1963–2013

concawe

years delivering science for Europe

review

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The oil companies' European association for environment, health and safety in refining and distribution

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Editor: Ken Rose, CONCAWE

Design and production: Words and Publications • words@words.co.uk

Foreword

Looking back ...

Michael Lane
Former Secretary General
CONCAWE

Welcome to this special 50th anniversary edition of CONCAWE's *Review*!

My photo, taken in 1963 when the CONCAWE Association was formed, shows a serious and worried looking boy, but I am quite sure that I was not (yet!) worrying about the refining industry or the environment!

There were some very foresighted people in our industry, however, who were thinking about these matters. Their vision about the growing importance of the environmental impacts of our industry led to the decision to pool industrial expertise in a new association, called Stichting CONCAWE: '**Con**servation of **C**lean **A**ir and **W**ater — **E**urope'. CONCAWE's early role in air and water quality research expanded later to include safety, health, fuel quality, refining economics and other areas, but the acronym has stayed the same for 50 years.

Society's concern for the environment has a long history, beginning with sanitation, hygiene and other related health improvements. Later, in the 19th century, the industrial revolution caused a deterioration of urban air quality but it wasn't until the late 20th century that a broader awareness of the need to protect the environment began to be discussed. For example, the US Environmental Protection Agency (EPA) was set up by Richard Nixon's administration in 1970, along with the first US Clean Air Act. Rachel Carson's book '*Silent Spring*', although controversial, certainly stimulated greater public awareness about chemical safety. In 1983, the United Nations set up the Brundtland Commission and its report, published in 1987, remains the most widely cited definition of sustainable development, widening environmental protection to include both social and economic dimensions.

Importantly, CONCAWE predates all of these governmental actions and was established years before the foundation of most of the well-known environmental non-governmental organisations (NGOs). Our industry has been acting for a very long time to understand and reduce our environmental impact, well before the emergence of societal and regulatory pressure. Our desire to do even better continues today. Research like that carried out by CONCAWE is essential, but well-considered legislation also has an important role to play, ensuring a 'level playing field' and allowing the most environmentally responsible companies to compete, both regionally and globally.

To put these issues in perspective, I found very interesting the following paragraph from a technical paper that was published by one of our six original member companies:

> *The atmospheric conditions that lead to frequent nuisance are factors beyond human control and their complete elimination will remain an illusion. However, research is ongoing into the possibilities of reducing environmental pollution as much as possible. Regulators and industry must work together because the road to success is arduous and the issues are more complex than expected. Looking at the results in our country and abroad, we are confident that we will succeed in delivering.*

Interestingly, this was the conclusion of a technical paper published in 1955, eight years before CONCAWE's formation, and it is as relevant today as it was forward-looking then.

Looking forward ...

Chris Beddoes
Director General
CONCAWE

Those people who formed CONCAWE, and who have maintained and enhanced its high standards of scientific work over the past 50 years, have left an important legacy. Mark Twain said, 'Study the past if you would define the future.' As we look forward and maintain the CONCAWE legacy we will recall these words. The EU has ambitious goals to reduce dramatically greenhouse gas emissions, improve resource efficiency and further improve air and water quality. If our industry is to survive and prosper, it will need to continue to evolve and play its part in meeting EU aims on a rational basis.

CONCAWE starts its future merged administratively with EUROPIA under one Director General. But CONCAWE's history of thorough, fact- and science-based analysis, both in shorter-term technical work and in longer-term research must continue if it is to provide the evidence base for rational decision making. Increasingly, this evidence base will include the cost and competitiveness implications of environmental protection. I look forward to helping to maintain CONCAWE's legacy, and helping to promote an internationally competitive and environmentally responsible downstream refining industry in Europe.

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Formation of ‘Stichting CONCAWE’ in 1963

Pat Docksey, BP

Fifty years ago—in October 1963—six international oil companies operating European refineries decided to form a new Study Group. The objective of this Study Group was to assist the oil companies in Western Europe at the time in their study of the scientific facts and mitigation options for air and water pollution. The documentary evidence shows that several of these companies had been considering this approach for many years, ultimately resulting in the formation of ‘Stichting CONCAWE’ in The Hague on 30 August 1963.

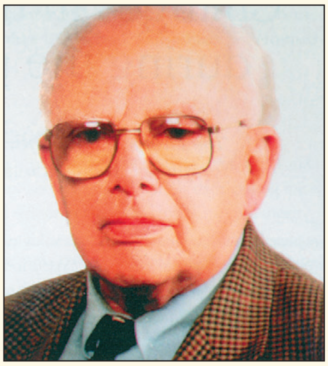
On 17 October 1973, Mr Pat Docksey, Manager of BP’s Research and Development Department, presented the following talk on the occasion of the 10th Anniversary of CONCAWE. Because he was also the first Chair of the CONCAWE Executive Committee and one of the six original ‘founding fathers’, Mr Docksey was well placed to provide his perspective on why and how CONCAWE was formed. His 1973 talk is reproduced below as it was presented.

Establishing the CONCAWE Association

My purpose today is to explain how CONCAWE came to be established and why it has assumed the form that it has. I have some right to speak on this, because I was involved from the earliest stages, but there are others whose memories of events would be equally valuable. One of these – **Dr Han Hoog of Shell** – has as great a claim as I to having been the driving force in establishing CONCAWE.

As one looks back at the technical progress made by the oil industry over the last forty years (1933 –1973), it can be seen that one of the driving forces for improving our processes and operations was to decrease the degree to which the users of our products and we ourselves caused pollution. Although the word ‘pollution’ was not in our day-to-day vocabulary in 1963, the possible effects which could arise from the use (or abuse) of our products was always in front of us.

I think that the oil industry could justly claim that the use of its products on the scale of the 1930s and 1940s brought about a minor degree of damage, in comparison with other sources of pollution at the time. But we were conscious that there could be damage in the future and that, as the use of petroleum products increased, our share of the total responsibility would increase also. This could rapidly become very serious and we had no intention of being caught in such a situation. By 1960, a considerable part of the technical thinking of many oil companies was devoted to identifying possible sources of pollution and seeking, in advance, ways to control them and minimise their effects.



Dr Han Hoog, Shell

In September 1962, Mr Duncan Dewdney of Esso (UK) judged that the problem of atmospheric pollution was becoming so important that the Institute of Petroleum (UK) ought to act. He suggested to the President (Mr J.C. Gridley, Mobil) that the IP Council should consider arranging a conference at which the subject could be openly discussed. He also suggested that the Institute should consider sponsoring research in this area.

It so happened that Dr Hoog and I had for some time been informally discussing the problems which were going to face the oil industry, particularly in Europe, as the situation developed. Our views were coloured by the steps which had already been taken within our companies to see that proper attention was being paid to these problems. We were convinced that the most important thing within a company was to ensure that all those who were responsible for policy or action were supplied with the scientific and technical facts, including the technical content and effect of legislation, in a consistent and well-digested form so that policy and action proceeded from a sound basis.

In British Petroleum, we had already set up an interdepartmental advisory group who received, assimilated, and disseminated to the various operating departments the results of our own research and of other research as it was published. This group also gathered experience in refining and marketing operations all over the world. I don’t think that we were unique by any means in having such a group. The system worked well and enabled us to establish the technical facts and to see that these facts were accepted as a basis for action. Further, it brought about a good exchange of information between operating centres which was valuable in uncovering areas where knowledge was lacking. This ensured that any research we did or any enquiry we had to collect the facts would fulfil a real need.

Dr Hoog and I felt that a system which worked beneficially inside our companies would also work beneficially inside the industry as a whole. Briefly, we thought that what was required was an inter-company Study Group of a permanent nature whose business would be to bring about some coordination of the research carried out in this field by the various companies, and who would watch and report the situation as it developed in various countries. This idea was different in both scope and method of attack from that originally put forward.

Regarding the scope, our feeling was that it would be wrong to restrict such an activity to one country. Such a restriction would greatly increase the difficulty of establishing the technical picture on any given topic. We envisaged that the Study Group should be a European one which would give us knowledge of the requirements and views over a large area, but one which at the same time was homogeneous as regards the general level of industry. There was a difficulty since there was not, and indeed there still is not (in 1973), a single official group on which the European oil industry can centre. Had there been such a group, it would have been natural to look to it to coordinate the industry in this field.

We placed emphasis on fact-finding and its accompanying activity of sifting and correlating the available data. Research projects would have to wait until a genuine gap in our knowledge was uncovered and the problem was defined. Because we felt that these views were important, we brought them to the attention of the IP Council.

Because Dr Hoog and I were both going to be in the USA in December 1962, we suggested to Mr Gridley that we would call together the representatives of a number of major companies and present our ideas. This meeting was held on December 19, 1962 and was attended by representatives of Esso, Mobil, Caltex, Shell, and BP. Dr Hoog and I had previously presented our ideas to Gulf and got their support. The basis of our talk was a note prepared by Dr Hoog, which stated clearly and in some detail the objectives we thought a ‘Pollution Abatement Committee for the Oil Industry’ should have and the scope of exchange of information.

At first, it was necessary to assure ourselves that such cooperation would not involve problems with US antitrust laws, despite the fact that it was intended to confine the membership to companies which operated in Europe. This point was rapidly disposed of and the meeting was able to agree on the desirability of an industry body of the sort that Dr Hoog outlined. It was agreed that the best way of bringing it into being would be to seek the sponsorship of the World Petroleum Congress, possibly in the form of a suitable announcement at their meeting to be held in Frankfurt in May 1963. Dr W.J. Sweeney of Esso, who was a leading member of the World Petroleum Council, undertook to ask them to give their support. This he subsequently did and the Congress as a whole formally gave their support at the May meeting in the following resolution:

> *The 6th World Petroleum Congress welcomes and encourages the work being carried out by ‘The Oil Refining Companies’ International Study Group for Clean Air and Water Conservation Activity (Western European Sector)’, and similar bodies and conferences, set up to study the scientific facts and data concerning pollution of air and water.*

In furtherance of its endorsement and encouragement of these scientific and technological endeavours, the 6th World Petroleum Congress instructs the Permanent Council to take whatever action they consider necessary and desirable to encourage this work between the 6th and 7th Congresses and to arrange a Panel Discussion of Pollution Problems at the 7th World Petroleum Congress.

The meeting in New York in December 1962 and the formal resolution of the WPC in May 1963 were the climactic events in the formation of CONCAWE. We had indeed moved quickly from September 1962 when our first very general ideas were discussed. That we had been able to do so was due to the personal friendships which have traditionally existed between members of the various major companies. It was also due to an understanding that there was a definable area of science and technology related to pollution inside which companies could exchange knowledge and experience without unduly exposing their technical secrets or surrendering their freedom to decide policy.

It was appreciated that policy which is primarily a matter of judgment requires the soundest basis of technical fact that can be achieved. Such a basis arrived at by discussions and investigations between experts from various companies and endorsed by them as a group would provide by far the soundest technical base available to any company.

By February 1963, we were reasonably confident that a Study Group of the sort we thought desirable would be established but much remained to be done if the group was to become active as soon as it was formally announced by the WPC. In order to promote action, we set up an Executive Committee composed of European representatives of the six companies I mentioned earlier.

One very important point was agreed in these early discussions. In the event that the group became established, Mr G.P. Lindmeier should be appointed Secretary General and act as Chief Executive of the group. He was shortly to retire from Shell but, as is so often the case with people in the oil industry who retire after considerable foreign service, he was still in the prime of life and had all the qualities required. His appointment was an extremely happy one and was a major contribution to the success of the Study Group.

It was also necessary to give the Study Group a place of residence and a name, which a few months before had been little more than an 'airy nothing'. As to the former, the Executive Committee decided that The Hague would be suitable. Since every effort had to be made to encourage the whole European industry to support and make use of the group, a central location was essential.

The selection, or perhaps one should say the invention, of a name which would fully express the full title of the Study Group and yet have general appeal was of some importance, although the discussion tended to be lighthearted.

There was one dreadful moment when we nearly finished up by calling ourselves CAWACO!

The final selection – CONCAWE – was derived from the words in the title which defines our area of activity – 'Conservation of Clean Air and Water – Europe'.

There was one dreadful moment when we nearly finished up by calling ourselves CAWACO!

The final selection—CONCAWE— was derived from the words in the title which defines our area of activity—'Conservation of Clean Air and Water – Europe'.

Since CONCAWE's headquarters would be in The Netherlands, it was decided that it should be established as a Stichting, a well-recognised legal entity under Dutch law. The very important decision was made that membership should be open to any company engaged in petroleum refining in Europe. It was felt that this limitation to refining companies was essential. It had the advantage that they were, on the one hand, active representatives of the industry in all European countries and, on the other, well able to bring into discussion the problems of crude oil quality and product quality with which they were intimately concerned.

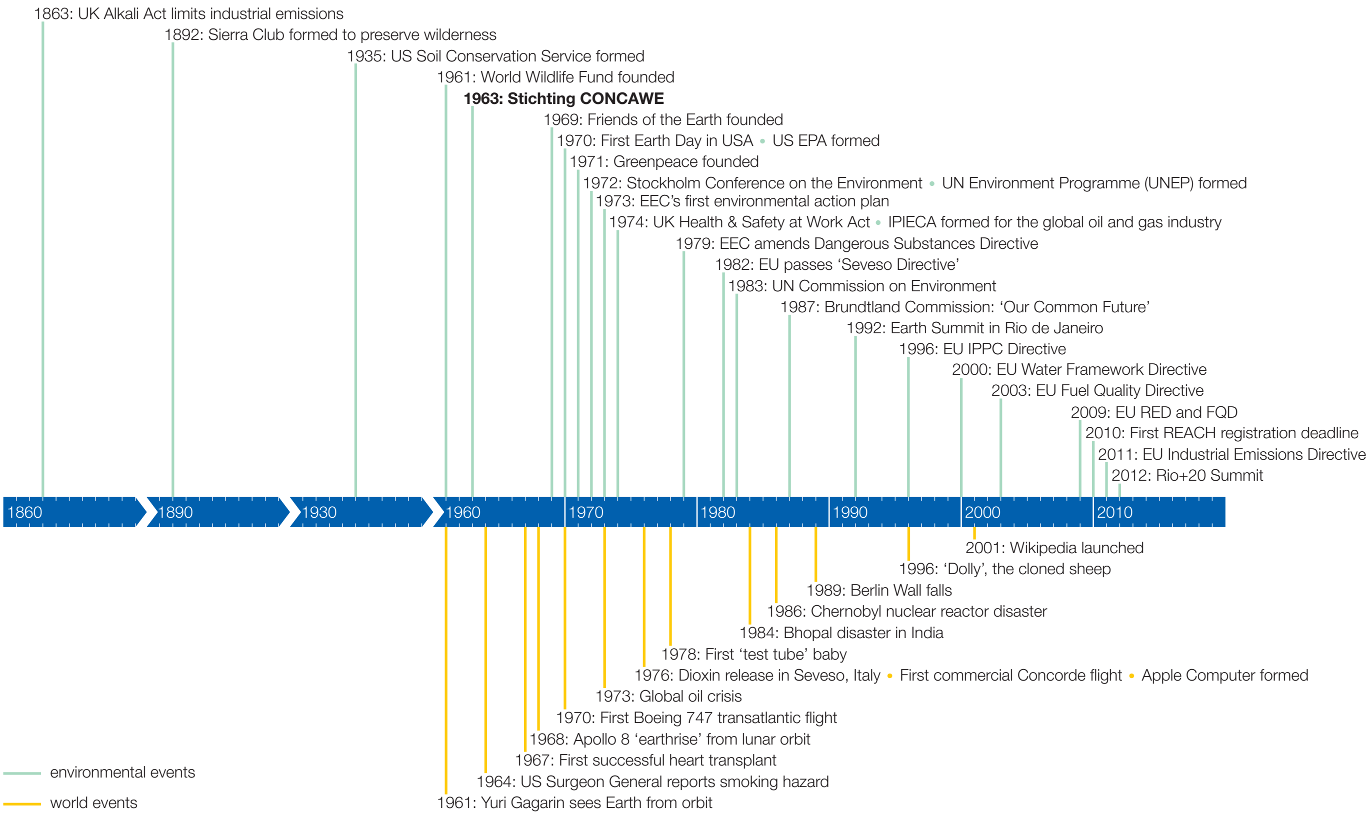
Further, it made clear that the Study Group was not trying to cover the field of petrochemicals, although any activity which normally took place within a refinery complex would be included. It also left open the question of whether ocean transport (which is far from being a

The first home of the CONCAWE Secretariat was in van Alkemadelaan in The Hague. CONCAWE moved to Brussels in 1992.

European activity) or production should be included. Indeed, at the time, crude oil production was at a low level in Europe. Finally, the expenditure required for the initial period was decided and methods by which member companies would support the research activities were agreed.

Thus, on October 17th, 1963, it was possible for the Executive Committee who had been meeting over a period of months to establish the constitution and method of finance, to meet as the Committee of Stichting CONCAWE, and to apply its mind immediately to the pressing technical problems that lie ahead.

Timeline of some significant world and environmental events



Fifty years of fuel quality and vehicle emissions

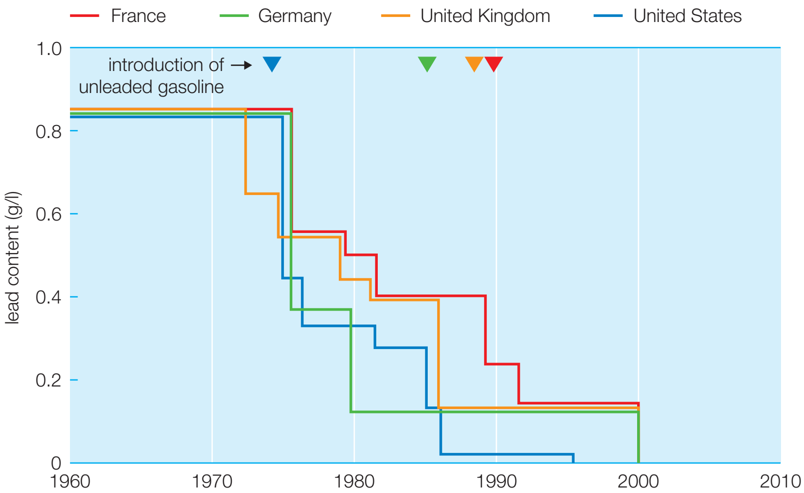
Ensuring vehicle performance through high quality fuels

In the late 1970s, with growing emphasis on urban air quality in Europe, CONCAWE embarked on new research related to fuels and vehicles. After only a few years, it became clear that fuel properties and specifications would be increasingly important to the future of the European refining industry, and considerable research was completed in the 1970s to better understand the impact of fuel composition on vehicle performance and emissions.

This early work led to the formation of the first Fuels and Emissions Management Group (FEMG) in 1982, almost 20 years after the formation of the CONCAWE Association. Since these early days, FEMG has been responsible for ensuring CONCAWE's strategic outlook on future vehicle and fuel developments, monitoring regulatory and vehicle developments, and overseeing a diverse portfolio of fuel quality and vehicle emissions research.

Since the 1980s, tremendous progress has been made in improving European air quality, in part by reducing emissions from road transport and other sectors, and major improvements in European fuel qualities have contributed to these reductions. Nevertheless, many challenges are still ahead, especially further reductions in pollutant emissions from vehicles while also reducing greenhouse gas (GHG) emissions from transport. In the near-term, these GHG reductions will largely come from improvements in engine and vehicle fuel consumption and by blending of GHG-reducing bio-blending components. Dealing with these challenges to fuel quality and performance will require a continuing focus on CONCAWE's founding principles: sound science, cost-effectiveness and transparency.

Figure 1 Eliminating lead from European gasoline



1960 to 1990: focus on gasoline

In CONCAWE's early years, much of the fuels and emissions work focused on the reduction and eventual elimination from gasoline of tetra-ethyl lead, a potent octane-enhancer and anti-valve recession additive that was widely used around the world. As concerns over the effects of lead in the environment grew, it was recognised that advances in refinery technologies would be required to reduce and then eliminate lead from gasoline while maintaining satisfactory octane quality for gasoline vehicles. Lead was finally eliminated from all European gasoline in 2000.

Eliminating lead as an octane improver required refineries to engineer new ways to increase the production of unleaded gasoline having a higher 'natural' octane. These improvements in new process units and catalysts resulted in investments and greater energy and hydrogen consumption. To find the best balance between refinery production of unleaded gasoline and vehicle performance, a major collaborative study was completed in the 1970–80s by the refining and auto industries to determine the optimum research and motor octane levels accounting for both vehicle performance and refinery operations. CONCAWE's 'Rational Use of Fuels In private Transport' (RUFIT) study provided the technical basis for this determination which established 95 RON (research octane number) as the new minimum for European market gasoline.

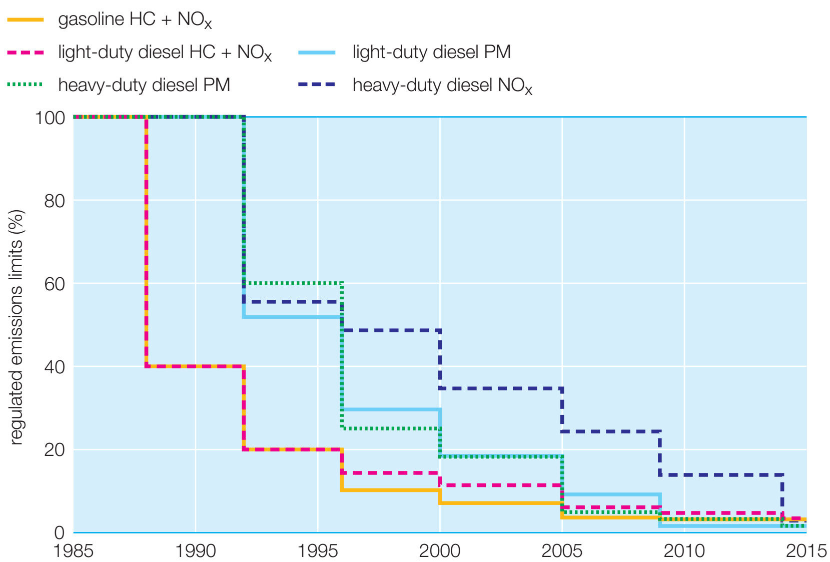
Because lead was also known to be a potent poison of catalytic metals, the move to unleaded gasoline that began in the 1980s also enabled the introduction of the first generation of cars equipped with rudimentary emissions aftertreatment systems, initially oxidation catalysts containing precious metals. These catalysts were able to reduce the concentrations of hydrocarbons and carbon monoxide in the engine's exhaust and initiated major advances in aftertreatment technologies that are still occurring today.

Evaporative emissions of volatile organic compounds (VOCs) from gasoline vehicles were also growing in importance due to urban air quality concerns. Several early CONCAWE studies also addressed this problem from the perspective of gasoline vapour pressure and evaporative emission control technologies, both at service stations and on board vehicles. This work demonstrated that 'closing up' the gasoline supply and distribution system using evaporative emissions controls at refineries, terminals and service stations and the use of activated carbon canisters on gasoline cars were effective at reducing fugitive VOC emissions. These measures were also found to be more cost-effective than dramatic reductions in the vapour pressure of gasoline.

While considerable attention was focused on gasoline vehicles, the relentless growth of the European diesel car and truck fleets brought forward new environmental questions related to diesel vehicle emissions and diesel fuel production. CONCAWE completed and reported its first studies on the relationships between diesel fuel composition and emissions from diesel engines and vehicles in the 1980s. A minimum 51 cetane number for European diesel fuel was later established as a satisfactory compromise between diesel vehicle performance and refinery production.

Below: impressive reductions in regulated vehicle emissions have been achieved since the late 1980s.

Figure 2 Reductions in regulated vehicle emissions, 1985–2015



As the regulatory requirements for vehicle emissions became more complex around the world, CONCAWE identified the need to compile information on the prevailing emissions regulations and fuel specifications in the world's major countries and markets. CONCAWE's first report on motor vehicle emissions legislation and fuel specifications was published in 1988 and has been periodically updated with the most recent version published in 2005.

1990 to 2000: Auto/Oil Programme

By the 1990s, it had become increasingly clear that a more 'integrated approach' between vehicle technologies and fuel composition would be needed in order to achieve the next big step in emissions performance. To provide the technical basis for future changes, the Auto/Oil I programme was completed between 1993 and 1995, including the European Programme on Emissions, Fuels and Engine technologies (EPEFE). CONCAWE's EPEFE task forces were actively involved with the European Commission and the vehicle industry in this Auto/Oil I research, contributing to the design, data collection and analysis of numerous emissions studies.

During this period, CONCAWE issued a series of reports on both gasoline and diesel fuel effects on vehicle emissions as well as on the economic impacts on EU refineries of changing fuel specifications. This work continued throughout the Auto/Oil II programme in the late 1990s followed in 2000 by a comprehensive evaluation of the effect of fuel sulphur content on advanced engines and exhaust aftertreatment systems.

Impressive reductions in regulated emissions limits have indeed been achieved for different vehicle types over several decades (Figure 2). Changes in fuel specifications have played a major role to enable these reductions, especially by removing sulphur from both gasoline and diesel fuels. The publication of the EU Fuels Directive (2003/17/EC) in March 2003 began the transition to 'sulphur-free' road fuels having less than 10 parts per million (ppm) sulphur which was completed in 2009. These fuels have enabled major advances in exhaust aftertreatment systems and engines that can achieve new vehicle emissions standards with ever-improving fuel efficiency.

Table 1 in the article on 'The evolution of oil refining in Europe' shows the long history of gasoline and diesel fuel specification changes over the 1994–2009 period, associated with the development of European-wide fuel standards by the European Committee for Standardisation (CEN). As a liaison organisation to CEN, CONCAWE has been actively involved in these developments for many years.

The Clean Air for Europe (CAFE) programme in the early 2000s provided the next important step to take a more integrated approach to air pollution, human health and the environment, taking into account emissions from all sources including transport. CONCAWE supported the CAFE approach which provided a framework within which different ways to improve air quality could be evaluated for their potential and cost-effectiveness for meeting environmental and health targets.

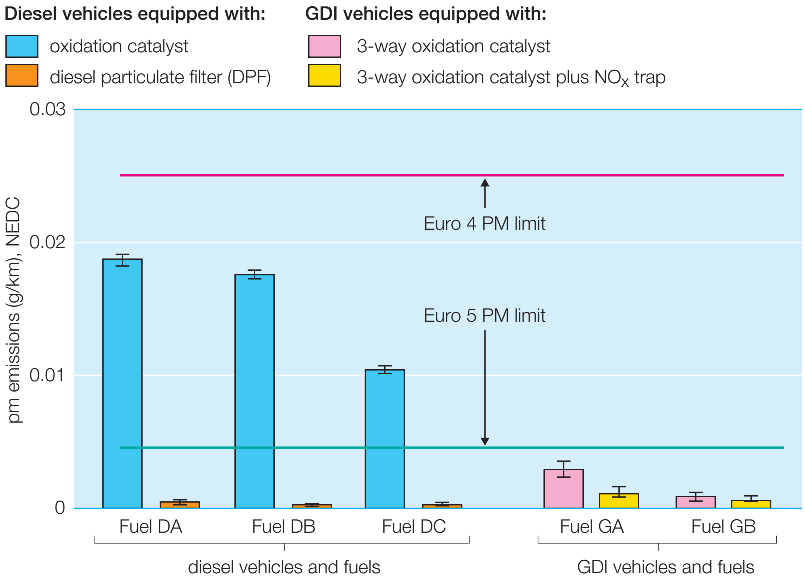
1993 to 2009: vehicle emissions limits

In addition to CAFE, other legislative and regulatory initiatives were under way to improve vehicle emissions performance. The 2003 EU Fuels Directive required that a thorough review of road fuel specifications would be completed by 2006. In parallel, the next stage of vehicle emissions standards, Euro 4/5 for passenger cars and Euro IV/V for heavy-duty engines, were implemented, with a primary focus on particulate matter (PM) and nitrogen oxide (NO_x) emissions from diesel engines.

In order to contribute to these technical evaluations, CONCAWE continued to test the effects of fuel composition on emissions from advanced engine and aftertreatment technologies as they entered or approached the market. Work completed on diesel vehicles and fuels in 2005 and 2010 showed that advanced engine technologies such as diesel particulate filters (DPFs) are much more effective for controlling PM emissions than further changes to diesel fuel properties (Figure 3).

While PM emissions are reduced using DPF technology, health-related questions are increasingly focused on much smaller particles generated during combustion, that can penetrate deeply into the human respiratory system. This new emphasis on ultrafine particles first required the development of robust measurement tools for particle number (PN) and size and CONCAWE has been an active contributor in this area. Through CONCAWE reports, SAE papers and research collaborations, the Particulates Consortium sponsored by the European Commission set the stage for the first new regulation on PN emissions, with the introduction of the Euro 5b PN emissions limit for diesel vehicles. Similar limits will be added for Gasoline Direct Injection (GDI) vehicles in 2014 (Figure 4).

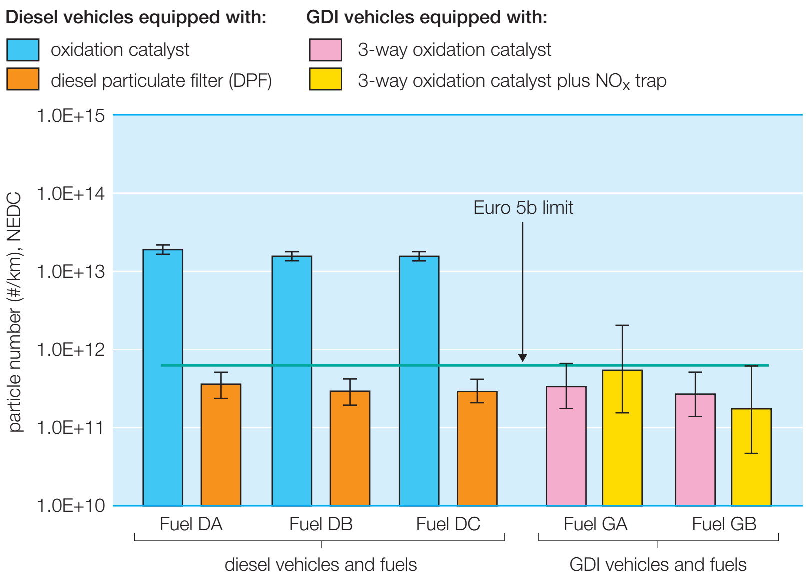
Figure 3 PM emissions from diesel and gasoline direct injection vehicles



Above: diesel cars with DPFs emit PM at well below the Euro 5 limit, whilst two GDI vehicles also produce very low PM emissions.

Below: while DPFs are also effective in reducing PN emissions, the effects of fuel composition on PN emissions are small.

Figure 4 PN emissions from diesel and gasoline direct injection vehicles



With higher than expected levels of transport-related nitrogen oxides in urban environments, new driving cycles will also be implemented in the coming decade to ensure that vehicles achieve low emissions performance over 'real world' driving compared to the regulatory cycles used for certifying performance in the vehicle testing laboratory.

From 2003 to 2020: GHG and biofuels

Although concerns about transport-related pollutant emissions have clearly not disappeared, vehicle fuel consumption and CO_2 emissions from transport have now become the focus for Europe's environmental agenda. With today's sulphur-free road fuels in the market, vehicle research has shown that more stringent fuel specifications offer only small environmental benefits while implementing them in the refinery would be likely to require new investments and lead to higher CO_2 emissions. CONCAWE has actively contributed to understanding this balance by pioneering work modelling the impact of changing fuel specifications on refinery operations. This work continues today at CONCAWE and is described in the article on 'The evolution of oil refining in Europe'.

Based on new regulations implemented in 2007, new passenger vehicles must meet fuel consumption targets in order to increasingly reduce GHG emissions from the vehicle fleet. For passenger cars, the 2014 limits require that each manufacturer's new vehicles must achieve 130 gCO_2/km, on a fleet-average basis, through engine and vehicle performance improvements, including hybridisation, alternative fuels, and other approaches. A fleet-average limit of 95 gCO_2/km is widely expected to be mandated for 2020 with potentially even lower fuel consumption targets beyond 2020. Mandatory targets are now in place for light-duty commercial vehicles and are being considered for trucks and buses.

In addition, the use of 'renewable' fuels to reduce the GHG footprint of transport fuels was required by European legislation, putting bio-blending components in sharp focus. While CONCAWE's first report on alternative fuels was published in 1995, a new literature review was published in 2002 on the overall energy and GHG potential for bio-derived components such as ethanol and fatty acid methyl esters (FAME). This review was completed in the context of the European Commission's (EC's) 2003 Biofuels Directive which encouraged the voluntary implementation of a variety of conventional and advanced fuel products derived from food crops and biomass.

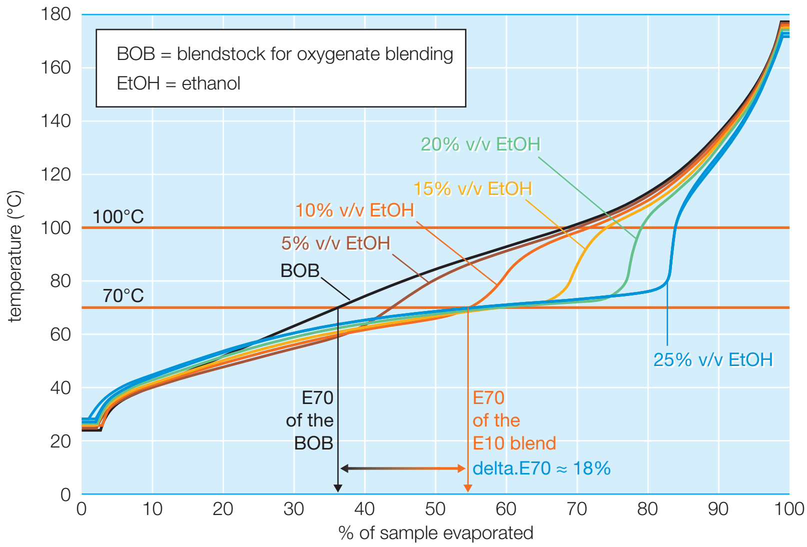
In 2009, two new regulations signalled the EC's intent to stimulate even greater use of renewable fuels in order to reduce GHG emissions from transport, improve energy security and support European agriculture. The Renewable Energy Directive (RED) mandated that 10% of transport fuels on an energy basis must be derived from sustainably produced, renewable sources by 2020. This percentage can include the use of bio-blending components, renewable electricity for vehicle recharging, biogas from waste materials, and other measures. Over the same time horizon, the Fuel Quality Directive (FQD) mandated that fuel suppliers must reduce the GHG emissions of transport fuels by at least 6% in 2020, compared to a 2010 baseline, primarily by blending certified bio-derived components.

To ensure the performance of these new fuel blends, CONCAWE has continued to represent the oil industry's efforts within CEN, drawing attention to the unusual effects that small amounts of some oxygenates, like ethanol, can have on gasoline properties (Figure 5). This work has resulted in changes to the CEN EN228 gasoline specification that are fully aligned with the FQD, allowing up to 3.7 wt% oxygen in gasoline using ethanol, ethers and other oxygenates. As shown by the 2012 market fuel survey results in Figure 6, different types and combinations of oxygenated blending components are increasingly used in European gasolines.

New specifications for FAME and for diesel fuel containing up to 7% v/v FAME have also been approved in the CEN EN590 diesel specification. To ensure that best practices to achieve 'fit for purpose' fuel products are also widely understood and implemented, CONCAWE has contributed several 'good housekeeping' guides to CEN covering fuel supply and distribution, and has actively supported the development of a new CEN standard for calculating the GHG footprint of bio-blending components.

Understanding the complexities from fuel production to consumption is also vitally important so that good regulatory decisions are made for future transport that achieve Europe's societal objectives. Beginning in 2001, CONCAWE began a long-term collaboration with the European Commission's Joint Research Centre (JRC) and the European Council for Automotive R&D (EUCAR). This 'JEC Consortium' successfully developed a comprehensive 'Well-to-Wheels' (WTW) methodology and comparative analysis of different combinations of fuels and powertrains that has become the European benchmark for contrasting different transport options. The first JEC WTW study in 2004 was updated in 2007 and 2011, and a fourth revision is expected in 2013 as more and better data become available. The JEC Consortium has also published work on vehicle performance and a detailed modelling study on biofuel implementation scenarios to achieve the 2020 RED and FQD mandates.

Figure 5 Effect of increasing ethanol content on the distillation curve of an ethanol/gasoline blend

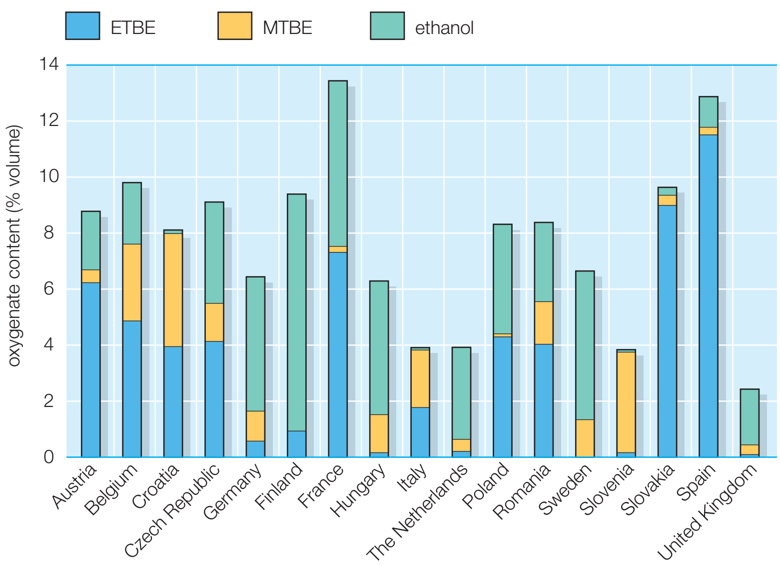


Looking ahead

Over many decades, CONCAWE's fuels and emissions research has contributed understanding to the substantial progress in reducing pollutant emissions from the transport sector. And, from a refining and fuel supply perspective, substantial changes in fuel specifications, especially the elimination of lead and sulphur, have enabled these reductions. Although vehicle emissions levels have fallen dramatically, more progress will be needed to achieve future reductions in ultrafine particles, nitrogen oxides and emissions of all pollutants under 'real world' driving conditions. New driving cycles and vehicle durability requirements will be implemented to ensure that pollutant emissions measured in the vehicle laboratory also represent the performance of vehicles on the road.

At the same time, better fuel consumption will be required from both light- and heavy-duty vehicles, and fuels containing bio-blending components will be used to support regulatory drivers for GHG reductions and energy security. Benefits can be expected as new generations of low emission vehicles enter the market, enabled by high quality, sulphur-free fuels. Alternative fuels and vehicles will also find their market niche based on performance, cost and customer acceptance. Engines, aftertreatment systems and vehicles will continue to diversify over the coming decades to achieve these important targets and should be objectively assessed on a 'well-to-wheels' basis. More than ever before, sound technical results will be needed to support future vehicle and fuel decisions and CONCAWE's fuels and emissions research will contribute to this effort.

Figure 6 2012 survey of European gasolines from 100 service stations



Fifty years of air quality conservation

As important today as it was 50 years ago

Looking back over 50 years, it is clear why attention to air quality and its relationship with emissions has been, and still is, one of the leading activities carried out by CONCAWE for its members. The concerns of the 1960s, addressed by enormous efforts over the following 50 years, are centre stage again in the 2013 'Year of Air' which re-focuses on urban air quality as it is affected by emissions from domestic, small industry, commercial and transport sources. The main difference is that now we deal in reducing residual risk as we move towards a policy target of 'zero' impact to human health and the environment, whereas 50 years ago the need was to address visible impacts.

In 1963, air quality was very much poorer for many than it is now, especially in towns and cities. Awareness of the links between air quality and health effects was high. Only 10 years earlier, the 'great smog' of London resulted in thousands of deaths. This led directly to the first UK Clean Air Act (1956). Focusing on urban air quality, this act sought to prevent emissions of 'black smoke' and reduce emissions of dust and grit by introducing emission control areas—'smokeless zones' where only certain fuels could be burned for domestic heating. Measures were taken on heavy transport—including steam-powered railways and inland waterway barges!

By 1960, environmental awareness was rising fast, as was the scientific understanding of air pollution and its causes. In parts of Europe, one in ten members of the population already owned a car. In the USA, ownership was four times greater and incidents of pollution related to automotive emissions were on the increase, especially in California. These episodes involved not just directly emitted substances but pollutants formed in the atmosphere by chemical reaction, i.e. 'photochemical smog'. In 1960, Congress funded the first studies on the health effects of air quality due to motor vehicle emissions. In 1963, the USA launched its first Clean Air Act with a focus on assisting emissions abatement. In 1964, Germany established TA Luft (Technical Instructions on Air Quality Control).

So, at the start of CONCAWE's life in 1963, air quality was already established as an important environmental issue and the science of air quality assessment and management was growing quickly. In 1962 Pasquill published his seminal book, *Atmospheric Diffusion: The Dispersion of Windborne Material from Industrial and other Sources.* In 1968 large-scale experiments were being carried out in the USA to determine input data for these types of stack models (which remained in use well into the 2000s). In 1968, the first revision of the UK Clean Air Act required tall stacks to ensure the 'safe dispersion' of industrial pollutants away from local sources.

Europe was also taking common action on environmental matters. The first European Action Programme started in 1973 and set the basis for what is now known as 'sustainable development'. It recommended actions on the control of air and water pollution. The 'polluter pays' principle was set out in 1974 in the Environmental Liability Directive (2004/35/CE) which also introduced the now familiar concepts of Integrated Pollution Prevention Control, environmental monitoring, external costs of pollution, protection of nature and biodiversity.

Internationally the consequences of the tall stacks policies of the 1960s were being felt. Long-range transport of SO_2 from Western Europe was found to have been causing damage to lakes and rivers, particularly in Scandinavia, and to forests in Scandinavia and Northern Europe. Although concentrations were small, the year-after-year deposition of material was turning water and soils acidic. The term 'acid rain' captured the public imagination. Because of the cross-border nature of long-range pollution, international collaborative action was needed to address it. The Convention on Long-range Transboundary Air Pollution (CLRTAP) was ratified in 1979. Under the Convention, protocol agreements were developed to reduce SO_2 (1985, 1994), NO_x (1988) and volatile organic compounds (VOCs) (1991). A first multi-pollutant, multi-effect protocol for all of these pollutants plus ammonia was adopted in Gothenburg in 1999.

In 1984 the Convention importantly put in place the cooperative European Monitoring and Evaluation Programme (EMEP) as its scientific base for the monitoring and evaluation of transboundary pollutants. The protocols under the Convention specify emission reductions to take place at a national scale by setting environmental objectives and determining the pollutant reductions needed for these to be met. A sound science base is needed to cover all the elements of this assessment. Activities include compiling emission inventories, modelling emission impacts, studying environmental damages, assessing control methods and their costs, and designing emission reduction scenarios to generate environmental gains. CONCAWE has worked closely with the EMEP scientists and national experts since the EMEP inception.

In 1993, the European Commission introduced its fifth Action Programme on the environment, entitled *Towards Sustainability*. This built on the strong growth in environmentalism in the late 1980s and, importantly, introduced the concept of setting both medium- and long-term objectives for environmental policy.

A major concern in the 1990s was to avoid the adverse effects of photochemical air pollution in Europe. The main emission culprits were VOC emissions, from solvent use, and from partial combustion, CO and NO_x. CONCAWE provided extensive assistance to the Commission during the development of Directive 94/63/EC on the control of VOC emissions resulting from the storage of petrol and its distribution from terminals to service stations (Stage 1). Rising motor emissions were a major source. The Auto/Oil programmes (1992–1996,1997–2000) were set up to identify environmental objectives for air quality, forecast future emissions and air quality, establish emission reduction targets (or appropriate functional relationships), collect input data on costs and effects of potential measures to reduce emissions, and carry out a cost-effectiveness assessment as a basis for a future air quality strategy. CONCAWE's contribution to these programmes included the assessment of air quality impacts and future emissions as well as the associated need for, and delivery of, changes to road fuels. Major changes that resulted were the lowering by stages of the sulphur content of fuel and the phase out of lead in gasoline. The sulphur content of gasoline and diesel was reduced to enable the activity of the catalyst devices that car manufacturers could fit to reduce vehicle emissions, and not exclusively to reduce the impacts of SO_2 in the environment.

As part of this work CONCAWE developed the 'STEERS' model to evaluate future fleet composition, fuel demand and automotive emissions. This model, much updated from Auto/Oil and coherent with the tools used for EU policy assessments, allows transport pollutant emissions to be forecast for the 2013 Air Quality Policy review.

The methodologies developed under the CLRTAP and set out in the EC's fifth Action Programme on the environment reflect the importance of setting environmental goals. CONCAWE fully supported (and still does) an environmental quality-driven approach to air-related issues because it leads to cost-effective solutions. An example of this was the technical input given to the European Commission when updating the 'Gas Oil Directive' (93/12/EEC). What would be an overall optimal sulphur content for heating gas oil that would reduce environmental impacts sufficiently but be readily able to be produced? By air quality modelling of two example cities (London and Cologne), assessing the refining implications of making lower sulphur gas oil and considering other strategies it was found that a sulphur content below 0.2% for heating oil was not justified. The air quality targets for SO_2 would be met through other legislation in force and by the increased use of natural gas. This study remarked on the CO_2 penalty of the extra refining steps which is now a cross-media effect of paramount importance.

CONCAWE has also used environmentally-driven arguments to assess how best to reduce the impact of emissions from international shipping. The results were to support discussions within the International Maritime Organization (IMO) which, at the time, was considering limiting the maximum sulphur content of ships' fuel. CONCAWE argued that it was more important to control those emissions close to land and in places where there was a definite adverse effect. CONCAWE went on to demonstrate that controls in a limited area were just as effective in reducing environmental impacts and much less costly to implement. This concept of 'SO_2 Emission Control Areas' (SECAs) was embraced in Annex VI of the International Convention for the Prevention of Pollution from Ships (the MARPOL Convention) in 1997, although the regulation did not come into force until 2005. Several SECAs are now in place around the world. When the convention was revised in 2006–2008, some stakeholders sought simplification of the regulation by proposing a global fuel specification that would have put impossible pressures on refineries. The European Commission was also keen to benefit from ship emission controls as it saw these as complementing on-land measures. CONCAWE provided technical support to other industry associations, the foremost being IPIECA, commissioning an emission inventory for the Mediterranean and carrying out several scenario studies. Much of this work involved European-wide air quality modelling. This was done through the Eurodelta project which looked at many important aspects of the modelling work done under CAFE (Clean Air for Europe). The two Eurodelta reports (2005, 2008) illustrated key uncertainty studies that need to take place in robust assessment of national emission ceilings.

The Air Quality Framework Directive (96/62/EC), which came into force in November 1996, paved the way for the Commission to adopt a more comprehensive environmental quality approach to future policy development. Its purpose was to establish a framework for the setting and attainment of air quality objectives as well as specific limit values for a list of air pollutants including SO_2, NO_2, particulate matter (PM), lead, ozone, benzene and CO. The Directive also set out requirements for the monitoring and assessment of air quality, and encouraged the development of measurement networks adding $PM_{2.5}$ (particulate matter with an aerodynamic diameter of 2.5 µm or less) to existing PM_{10}. In the years since 2000, focus has been on these smaller particles as being most harmful to human health. As mentioned earlier, the (1999) Gothenburg Protocol under the CLRTAP was the first multi-effect and multi-pollutant protocol. It set emission ceilings to be met by 2010 for four major pollutants. The EU adopted slightly stricter ceilings for this date using the same modelling. This was done through the National Emissions Ceilings Directive (NECD) in 2001. CONCAWE played an active part in the development of both the Gothenburg Protocol and the NECD, and especially in the subsequent EU activity known as CAFE. CONCAWE developed its own version of the Integrated Assessment Model that is at the heart of the cost-effectiveness policy. This model, known as SMARTER, has been invaluable in allowing scenario testing of the policy approach, and in assessing many of the underlying inputs.

CAFE (1999–2004) was a large project following the Gothenburg Protocol, and which aimed to meet the objectives set out in the fifth and sixth Framework programmes, i.e. to have a long-term strategy for air quality, hereafter the Thematic Strategy on Air Pollution (TSAP). The present structure of the CONCAWE air quality team was designed to ensure that we could contribute on all areas—energy scenarios, emissions, modelling for dispersion and impacts, costs and the assessment of cost-effectiveness. A new area for CONCAWE was the quantification of health effects and their monetisation. A special cost-benefit group was formed for this new area of expertise and this remains active today.

It was expected that the TSAP would deliver two major policy proposals: a revised air quality directive and a revised NECD for Europe. The air quality directive was revised but without change to the limit values set in 1996. These were limits that progressively decreased from 2000, to reach their current values in 2005, so as to allow time for management plans to work and for assessment data to be available. Proposals for a new NECD were not made due to a combination of events. Firstly 'climate' began to be recognised as a major issue at the beginning of the decade and reached critical mass during CAFE. The legislation on Climate and Energy (2008) changed the view of the future, and hence the future emissions embedded in the CAFE technical assessments. Secondly, the financial crisis (2007) in Europe struck and meant that the view of the future was even more uncertain.

CONCAWE has always supported its Member Companies and contributed to the CLRTAP programme by advising on emissions. We review published information on emission factors and feed these into the Task Force on Emission Inventories and Projections (TFEIP) for publication in the emissions inventory guidebook. In 2007 we formalised this with an 'ever-green' emissions guide-book to assist regulatory reporting under the European Pollutant Emission Register, now replaced by the European Pollutant Release and Transfer Register (E-PRTR). An update was published in 2009 and another will be prepared in 2013. As part of this work we conduct studies to fill knowledge gaps where data is not available from published literature. Since 2010 we have been running projects to quantify fugitive emissions from refinery sources and to improve methods for quantification by remote sensing. Reports on this work are being prepared for publication in 2013 and will set the basis for a remote sensing protocol.

Also since 2007, and of foremost importance today, is the refinery contribution to the review of the reference document describing the best available techniques to use to abate emissions in the refinery industry, known as the REF BREF for short. Since the Directive on Industrial Emissions came into force in December 2010, these reference documents, and especially their conclusions, have a legally binding nature. The BREF process will finish in March 2013 from a technical aspect. CONCAWE has contributed very significantly over the review process which was launched in 2008. There have been many challenges along the way as the review started under one set of legislation and ended under another.

So what challenges are immediately ahead? This year, 2013, has been decreed the 'Year of Air' by the EU Commission and, by reviewing the Thematic Strategy on Air Pollution, will set objectives for emissions reduction and air quality improvements for the next 15 years (time horizon 2025–2030). To do this, the scientific basis must be sound, uncertainties explored and expectations should be realistic. CONCAWE will contribute to this debate recognising that the years from the present to 2020 will be very challenging. Several key policy actions on decarbonisation, energy efficiency, transport and industrial emissions control take effect.

Three major challenges stand out:

- The emissions of NO_x from road transport seem intractable. Since 2008 it has been recognised that the technical measures in place in good faith had not been as effective as expected.
- The emissions of ammonia from agriculture simply have to be reduced if the worst environmental pressures, eutrophication and the health effects of secondary particulates are to be eased. Improvement targets being considered in the context of the 'Year of Air' need substantial reductions. Compensation by reducing NO_x from remaining industry and transport seems unlikely to be possible and hugely expensive.
- The third challenge is to account for the interplay between climate and air quality. Removing sulphur has, in particular, led to awareness of the importance of cooling emissions having a short lifetime in the atmosphere. Abatement leads immediately (in climate terms) to a perturbation which may have environmental consequences that climate modelling is not able yet to answer. Compensation by removing short-lived climate forcers is sought—hence discussions on limiting black carbon and methane sit across the air quality and climate barriers.

In 1963 focus was on abatement of local emission effects. One of the policy measures put in place, tall stacks for industry, helped resolve local air quality issues, but the resulting long-range transport of SO_2 across borders led to another problem—that of acidification. The collaborative and international efforts have largely resolved the acidification issue, but new questions are now emerging about the effects on climate, as it is recognised that SO_2 emissions have a globally significant cooling effect. The relationship between climate change and the air pollutants that we have been dealing with over the past 50 years has become an important element of the air quality debate. Concerns have moved from local level to global level in just 50 years. What further developments will the next 50 years bring?

Providing information and guidance on water and soil management

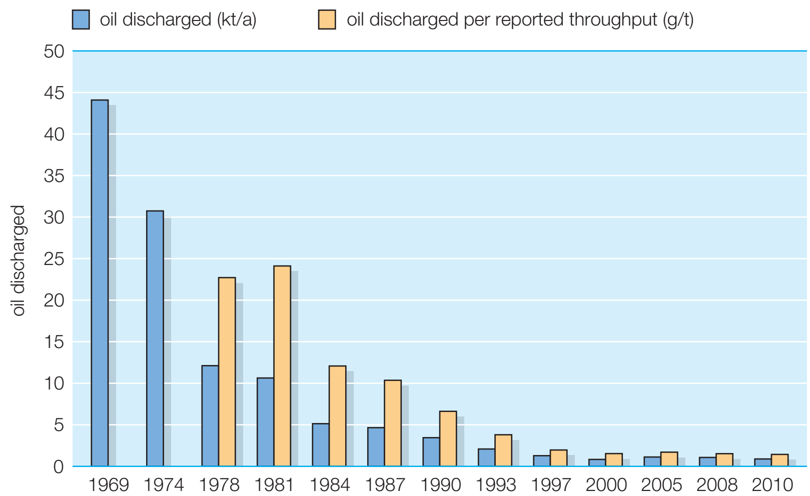
Understanding the aquatic ecosystem and demonstrating continual reduction of the refining sector's impacts

When CONCAWE was formed in 1963, the conservation of Europe's water resources was one of the main drivers, following the commitment made by the industry at the 6th World Petroleum Congress. Water remains an essential resource that has, over the years, come progressively higher on the international agenda because of its intimate relationship with both human health and ecosystem development. In the 50 years of CONCAWE's existence, water quality in Europe has improved steadily and the contribution of the refining sector to this improvement cannot be ignored. Today, almost 50% of Europe's surface and groundwater bodies are classed as being of at least 'good' status (as defined in the Water Framework Directive) and, for those that do not meet this standard, the impact of the refining sector has been shown to be minimal. Nevertheless there is growing pressure on water resources in terms of chemical and ecological quality, of the quantity used or consumed, and of equitable access to good quality water.

Water in oil refining: continuous improvement over the years

Like most heavy industries, oil refineries use large quantities of water, handling roughly six times more water than the quantity of crude oil they process. The industry has made important progress in reducing its water demand and improving the quality of its discharges into the environment, especially into fresh water systems.

Figure 1 Oil discharged from refineries in Europe



Effective management of water, from supply through handling and treating to final discharge into the environment, is a key requirement for the efficient and responsible operation of a modern refinery and a condition for its acceptance by the community.

The name CONCAWE includes 'clean water', one of the first issues dealt with by the Association. In the early years much work was devoted to reducing oil discharges from refineries. Figure 1 illustrates the evolution over the past four decades with reductions of more than 99% in the total oil discharged and 94% in the quantity of oil discharged per unit of crude oil intake[1]. This has been achieved through the installation of increasingly sophisticated treatment systems, which also allowed significant reductions in the discharge of oil and most other refinery pollutants. This represents a major success considering that the production volume has more than doubled and the refineries included in the analysis have broadened over time.

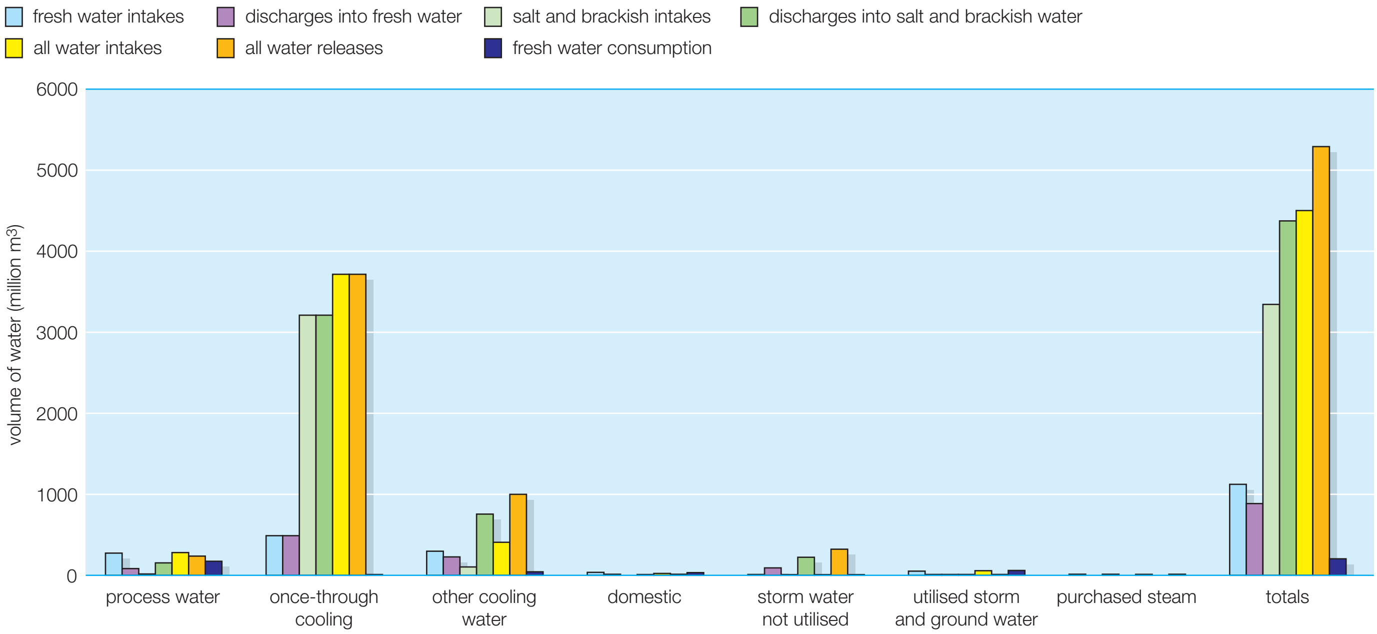
In 2010, the total amount of non-chlorine pollutants reported by the European refining industry to the European Pollutant Release and Transfer Register (E-PRTR) accounted for only 0.82% of total industrial discharges in the EU. In comparison, discharges by the urban waste water treatment (UWWT) sector accounted for 54% of the reported load[2]. This is a clear demonstration that today's environmental issues are no longer dominated by the activities of heavy industry in general, and the refining industry in particular.

As the level of pollutants discharged has reduced, the focus of attention is shifting towards minimising the impact of industrial water usage on the environment, specifically where this concerns fresh water use and consumption. The refinery sector's water intakes, discharges and fresh water consumption are presented in Figure 2, as reported in 2010. Although considerable amounts of water are associated with refinery opera-

[1] CONCAWE report 6/12

[2] In our studies, the entire refining sector has reported, while, for the UWWT, only larger installations (> 100,000 p.e.) have to report their emissions covering less than 50% of UWWT discharges. For this reason, the reported amount from the refining sector is representative of at most 40% of the total load from UWWT discharges.

Figure 2 Refinery sector water intake, discharges and fresh water consumption, 2010

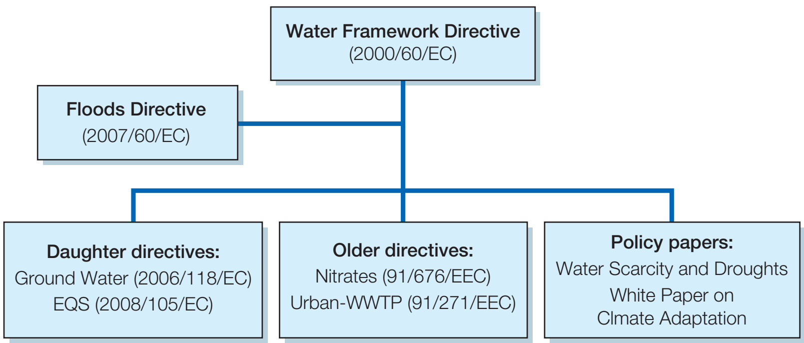


tions, the total fresh water consumption (that is, the volume of water that will no longer be available to other users after discharge or use) is now 225 million m^3 or, on average only 0.31 m^3 per tonne of crude oil processed. In 1969, a similar survey showed that this figure was 8 m^3 per tonne of crude oil processed, evidence that the refining sector has succeeded in significantly reducing its fresh water footprint, contributing to more sustainable water use.

The European regulatory framework

In 2000, the Water Framework Directive (WFD, 2000/60/EC) was adopted, drawing together related but hitherto separate pieces of European water legislation. This comprehensive piece of legislation covers water resources, water quality and hazardous substances and provides an integrated approach to water management. Water quality is defined both in conventional chemical terms and also in terms of ecological quality. Since the Directive was enacted in 2000, several daughter and supportive directives and policy papers have been adopted and published. These, and some earlier directives, comprise the EU water policy framework that is depicted in Figure 3. The WFD is implemented through a Common Implementation Strategy (CIS) that sets out the techniques and requirements for achieving its expectations, by developing Commission guidance on specific topics and by scientifically assessing the available information for setting Environmental Quality Standards (EQSs).

Figure 3 The EU water policy framework



As part of the European 'Year of Water' in 2012, a major water policy fitness check was performed, which concluded that the framework is still robust enough to deliver the desired water quality and quantity. However, meeting the framework's expectations is proving more difficult mainly due to non-compliance and poor implementation by Member States. The review also identified a lack of robust data to demonstrate progress.

The fitness check was an important step leading to a 'Blueprint to Safeguard Europe's Water Resources'. According to the Commission, the quality of EU waters is not improving rapidly enough and additional policy measures are needed to accelerate progress and to ensure the equitable availability of water of the desired quality. Moreover, the Blueprint places strong emphasis on ecosystem functioning, indicating the need to halt biodiversity loss and, where possible, initiate reversal of biodiversity losses already observed. It also includes the management and utilisation of the essential ecosystem services that can only prosper in sufficiently diverse ecosystems.

To achieve these goals, the Blueprint and the Policy Fitness Check clearly indicated that the policy framework alone is insufficient. However, the legislative toolbox does not require more instruments—these are already in place. There is extensive legislation mentioned in support of the water policy framework objectives, including: the Strategic Environmental Assessment (2001/42/EC) and Impact Assessment (85/337/EEC) Directives that require an evaluation of impacts of future investments or installation changes; the Marine Strategy Framework Directive (MSFD, 2008/56/EC—the marine equivalent of the WFD); and the Habitat (92/43/EEC) and Birds (2009/147/EC) Directives that should deliver the target of no net loss of biodiversity. Furthermore, the Environmental Liability (2004/35/EC) and Environmental Crime (2008/99/EU) Directives enable funding of restoration by, and prosecuting of, the polluter. The Industrial Emissions Directive (IED, 2010/75/EU) addresses pollution by industrial point sources and the REACH Regulation, the Plant Protection Products and Biocides legislation regulates substances that might contribute to impacts on water quality. Finally, the EU climate policy framework and the Renewable Energy Directive (RED, 2009/28/EU) also address water issues.

CONCAWE has invested considerable effort in supporting implementation of the WFD, contributing to several guidelines and ensuring that EQSs were only derived for substances that require EU-wide standards, and that these reflect the latest ecotoxicological data on those substances. By providing monitoring and effect data, only a few refinery-relevant substances remain on the priority list that was adopted in 2008. The revision of this list is now in the legislative process for adoption by the Council and the Parliament. Similar activities have been performed with respect to the implementation of the EU Groundwater Directive. Furthermore, contributions were made to the CIS guidance on mixing zones and emission inventories.

Industrial emissions, including those of the refining sector, are subject to the Integrated Pollution Prevention and Control Directive (IPPC) that considered the use of Best Available Techniques (BAT) to optimise resource use, minimise pollutant generation and control discharges in the major industrial sectors. Since its adoption in 1996, this Directive was updated in 2008 and replaced by the IED in 2010. Although its scope is much wider, water use and effluent quality are amongst the key issues addressed by the IED. The 'European IPPC Bureau', established in Seville, has been given the task of preparing and/or reviewing the BAT Reference documents (so-called 'BREFs') for all the industries covered by the IED. The BREF BAT conclusions under the IED, unlike the IPPC, are given a legally binding status for the derivation of permit conditions and emission limit values.

In 2008 the review of the 2003 Refinery BREF (REF BREF) was initiated, which meant that CONCAWE acted on behalf of the refining industry in the Bureau's Technical Working Group (TWG), providing significant technical input, both as actual performance data and operational experience. Given the change in status under the IED of the BAT conclusions, the first challenge was to define what would constitute BAT for refineries, what emissions these technologies could be expected to produce and what their costs would be. In 2011, CONCAWE carried out a comprehensive refinery effluent survey building on earlier work performed in 2006 and 2009, that proved to be an extremely useful source of information during the BREF drafting and commenting process. The full results of this survey covering the year 2010 will be published in 2013.

The revision of the REF BREF is still ongoing and CONCAWE provided extensive comments (500 from a total of 1248 received by the Bureau) on the last draft document. In early 2013, a final meeting of the TWG will be held, where CONCAWE, supported by member company experts, will express their views on the comments that were accepted or rejected by the Bureau, to ensure that the REF BREF is a balanced technical document.

A similar but less arduous process is under way for the review of the so-called horizontal BREF document from 2003 on Common Waste Water and Waste Gas Treatment Systems. CONCAWE has made a significant contribution in several areas related to our industry sector. Although labelled a Chemicals BREF, this horizontal BREF is intended to apply to a range of industry sectors. However, a number of the topics covered are also mentioned within the Refinery BREF. CONCAWE's involvement in the review process is aiming to ensure that areas relating to the refining sector are exclusively covered by the REF BREF and that these are tailored to our sector's performance and capabilities.

Convention for the Protection of the Marine Environment of the North-East Atlantic (the 'OSPAR Convention')

OSPAR remains an important actor on the European marine water scene, as it deals not only with the seas but indirectly with all main water basins discharging into the North Sea or Eastern Atlantic. As a direct result of the large reductions in oil discharged by refineries as indicated by the CONCAWE data, OSPAR decided a few years ago that refineries should now have a low priority and discontinued their specific refinery effluent surveys. OSPAR still request CONCAWE data to monitor the status, and these data are regularly reported in the effluent survey reports.

OSPAR is leading the development of biological effects measurements to understand the impacts of aqueous discharges on the environment. Such an approach seeks to monitor effects either directly upon the environment (e.g. studies of population effects or species diversity) or using surrogates for the environment (e.g. test species with response to certain stimuli or stresses resulting from the presence of pollutants). This approach is also now being more commonly adopted within Member States and the EU itself (particularly in the WFD). CONCAWE has participated in the OSPAR expert group on whole effluent assessment (WEA) and has carried out a demonstration programme on the applicability of WEA methods to real discharges. The methodologies being evaluated could become a standard part of future legislation both for OSPAR and the EU, covering virtually all European countries. WEA is a tool whereby a sample of effluent is assessed against a range of biological tests (potentially covering e.g. acute and chronic toxicity, potential to bio-accumulate, persistence and some genetic effects) to assess whether the effluent may cause harm to the environment. There are many questions unresolved as yet on the efficacy of this type of testing, which could potentially lead to very stringent requirements for effluent control. CONCAWE is bringing data from member company studies into the debate, particularly in the areas of persistence and potential for bioaccumulation[3].

There is no doubt that the introduction of biological effects measurements, in addition to the more traditional chemical-specific approaches currently used to regulate refineries, will cause different issues to become a priority. It is argued that such an approach more closely addresses the actual impacts upon the environment. It is also a potential benefit to operators, allowing a more readily acceptable demonstration of no harm to the environment. The key issue is whether the measurements made in a laboratory relate to real environmental effects in the receiving water. This is particularly so for some of the longer-term chronic and genetic tests where the relation to actual population effects is not always clear. This could lead to significant changes to effluent control systems which may not achieve real environmental improvements.

Soil and groundwater remediation

Besides direct water issues, CONCAWE's Water and Soil Management Group (WSMG) has also focused on the assessment and clean-up of contaminated land, because of the potential impact on groundwater resources. WSMG published guidelines for a risk assessment-based method for determining whether there is a need to clean up contaminated sites and, if

[3] CONCAWE report 1/12

so, what standards should be used for evaluating the final level of contaminants. These guidelines have recently been revised and expanded. During the 1980s CONCAWE also published a series of field guides on oil spill control. Although these date back more than 20 years, much of the information is still relevant and the guides remain an acknowledged and valuable resource in this area, frequently requested by member companies and third parties.

In addition, CONCAWE has published a sensitivity study on retail stations in several European Countries[4] and a study on the behaviour of Gasoline Ether Oxygenates in the environment in support of site remediation strategies in case of fuel spills[5].

Outlook

From Rio (1992), via Johannesburg (2002) through the Rio Earth Summit in 2012, debate on sustainable development has focused on water as an essential resource for life, shifting attitudes to water in a manner not applied to most other raw materials. The EU has taken a positive lead in the debate on water resources and indeed the WFD opens with the phrase 'Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such'. The IED Directive mentions ensuring prudent management of natural resources and uses water as one of its examples, specifically requiring operators to take measures to use water effectively within their installations.

Although the quality of Europe's waters has experienced significant improvements, the conclusions of the Blueprint, the Policy Fitness Check and the desire to align the MSFD with the WFD is likely to stimulate many implementation initiatives to demonstrate that the targets are met. These will most likely affect the Member States, who will turn to industry even though the facts show that industry is not the major contributor to today's environmental issues.

Moreover, water resources remain under pressure in Europe. Agriculture and households appear to be the larger water users in most areas, but industry also plays a significant part. Water remains essential for efficient refinery operation and some refineries can be large local users of water. It is important that all sectors work together to understand and manage the local and regional water supply and quality issues and ensure that the equitable use perspective advocated in the Blueprint is resolved by mutual agreement rather than by regulatory action.

CONCAWE's activities in the areas of water cover a range of environmental and operational issues within the refining industry, ranging from water supply and resource management through operational optimisation to minimisation of waste generation and environmental impact. The information generated through surveys and studies continues to be recognised by both the industry and third parties, including regulators, as a valuable contribution to the ongoing debates. As water has risen up the political agenda the importance of this contribution can only increase.

In response to the EU's biodiversity aspirations, the refining sector should continue to integrate biodiversity and ecosystem services management into its strategy and daily operations. CONCAWE, through WSMG, will support its members in this activity.

[4] CONCAWE report 1/11

[5] CONCAWE report 4/12

Health research over 50 years

Understanding the health issues behind environmental concerns and regulatory initiatives

CONCAWE has been working on health issues since its formation in 1963. In the early years, the focus of this work was on occupational health hazards and risks in the refining industry. Over the years, especially in the past decade, broader human health issues have been at the centre of environmental and regulatory debate, with 'health effects' increasingly being the driver behind environmental improvement and occupational health initiatives. Against this background, CONCAWE's health research has expanded to deal with these new and emerging issues.

Health issues are complex and need to be addressed by experts in several different areas. Through its member companies, CONCAWE has been able to maintain, as its 'Health Management Group', a strong team of occupational physicians, toxicologists, industrial hygienists, exposure and risk assessors, and product stewards with particular expertise in oil industry-related issues. Academic researchers are also called upon to undertake specialised research, as appropriate.

In the 40th anniversary *Review* (October 2003), we reviewed CONCAWE's involvement in three initiatives: (1) the Clean Air for Europe Programme (CAFE), an EU strategy for air quality management; (2) chemicals legislation and the increasing demand to inform the public about health and environmental hazards of chemicals; and (3) a global environment and health strategy with a special focus on children (EU SCALE initiative). Interestingly, these initiatives from 10 years ago continue to influence CONCAWE's work on health research, its objectives being to identify key health-related issues and gaps, develop cost-effective, leveraged research programmes to address these gaps, and provide CONCAWE members with advice, guidance and support on the significance of these issues based on scientific and professional evaluations.

In this 50th anniversary article, we summarise CONCAWE's involvement in three new or expanded areas: chemicals legislation and its requirements under REACH; the health effects of air pollution; and benzene product stewardship.

Chemicals legislation

Ten years ago, in 2003, the precise requirements of REACH were still under discussion. In anticipation and preparation for what the REACH requirements would be, CONCAWE initiated an ambitious programme to acquire information on human exposures, in the form of both descriptions of use and measured data. It was clear that these types of data would be necessary for the risk assessment of petroleum products. As a consequence, between 2000 and 2005, exposure data reviews and measuring campaigns were implemented to obtain current exposure information on gasoline, gas oils, kerosenes and other petroleum substances. Methodologies for monitoring airborne levels of LPG and bitumen fumes were also updated.

In the past 10 years, in addition to maintaining and evaluating the toxicology database for 22 petroleum substance categories, and submitting the dossiers to the European Chemicals Agency (ECHA) in 2010, CONCAWE has prepared for REACH by initiating several health research activities to anticipate potential data needs. Three key health science contributions that established the industry standard and provided valuable insights towards the REACH effort were:

- Development of the exposure assessment tools for both workers and consumers: CONCAWE developed the approach for characterising the health risks for workers and consumers from identified uses in different categories of petroleum substances. During the development of its exposure estimates, CONCAWE identified the need to include additional risk management measures in its estimates based on commonly applied controls during the manufacture and use of petroleum substances. This approach has become accepted as the standard industry methodology.
- Derivation of the 'Derived No Effect Level' (DNEL) for petroleum substances categories: CONCAWE reviewed the toxicology database on petroleum substances and calculated the REACH required DNELs. This involved extensive review of the available data and the approach developed by CONCAWE was published in a peer-reviewed journal.
- Justification to support the industry assessment of the cancer hazard classification of residual aromatic extracts (RAEs): CONCAWE developed a round

robin research programme which showed that, by using a well-established modified mutagenicity test, the carcinogenic hazard of an RAE could be predicted. The results of this programme provided the underpinning for the industry's technical justification of the cancer classification for RAEs.

To further support the assumptions on the exposure assessments for REACH, CONCAWE prepared a compendium of the assumptions related to REACH chemical safety assessments for petroleum substances. In addition, dermal exposure studies were commissioned to provide further technical justification for the assumptions used in the exposure assessments. And as part of the REACH requirement, interim risk management measures for use of petroleum substances with testing proposals were prepared and communicated. (See also the 'Petroleum Products' article in this *Review*.)

Health impacts of air quality

Ten years ago, the EU strategy for air quality management was based on the Clean Air For Europe (CAFE) programme. The main driver for the regulatory measures proposed by the European Commission was, and still is, the protection of human health from air pollution, especially particulate matter (PM), nitrogen oxides and ozone.

Recently, the World Health Organization (WHO) Task Force on Health coordinated an international project called REVIHAAP (Review of the Evidence on Health Aspects of Air Pollution) and HRAPIE (Health Risk of Air Pollution In Europe). These initiatives provide the scientific assessment to the European Commission and its stakeholders on the evidence for human health impacts from air pollution. This assessment is based on a review of the latest scientific evidence of those air pollutants regulated in recent Directives (2008/50/EC and 2004/107/EC). Pollutants have been expanded to include nitrogen dioxide, sulphur dioxide, some heavy metals, and polycyclic aromatic hydrocarbons, as well as a growing concern about indoor exposure to air pollutants.

To date, the evaluation of the health effects of airborne pollutants relies mostly on observational epidemiology investigations rather than on data from controlled clinical and toxicological studies. Not surprisingly, CONCAWE voiced concerns within the CAFE programme about the reliability of many study findings, and continues to emphasise the need for sound science in regulatory decision making. Scientific issues that have been routinely raised include: adequacy of the science to determine limit values, uncertainty in the dose-response functions, accuracy with which personal exposures are estimated, the ability to quantify life expectancy effects of air pollution changes, and possible double-counting of air pollutant effects.

Anticipating 2013 as the 'Year of Air', CONCAWE implemented several projects focused on addressing health data gaps in air pollution studies. These included:

- VE3SPA study (Validation of ESCAPE Exposure EstimateS using Personal exposure Assessment), a project that monitored personal exposure to key pollutants, and where the data have been used to evaluate whether the commonly used Land Regression models (area monitoring) can be reliably used to predict personal exposures at the street level.
- Critical review of the epidemiology data on key pollutants (PM, ozone, NO_x and SO_x) which provided an understanding of the current science and the basis for CONCAWE's contributions to the regulatory discussions on these pollutants.
- Human Exposure to Ozone in a Controlled Environment Study which was conducted at the University of Rochester in New York and evaluated ozone exposure under controlled conditions, measuring various cardio-respiratory parameters.

The health impacts of air pollution are also of interest at other international organisations such as the International Agency for Research on Cancer (IARC). IARC is part of the WHO and reviews and categorises chemicals as to their carcinogenic hazard potential. IARC recently designated diesel engine exhaust as a 'proven' human carcinogen, gasoline engine exhaust as 'possibly' carcinogenic to humans, and occupational exposure to bitumen and their emissions as either 'possibly' or 'probably' carcinogenic to humans depending on the type of bitumen and its occupational sector of use. IARC has undertaken a series of reviews of agents and these reviews may contribute to an assessment of ambient air pollution later in 2013.

CONCAWE has also responded to the regulatory focus on air pollution by organising two technical workshops in 2007 and 2009, which brought together the researchers and stakeholders to discuss key issues in the field of air quality science. These workshops helped confirm CONCAWE's position as a valued and respected contributor to the debate. CONCAWE will continue to engage in health-related discussions on air pollution to promote the use of sound science in policy decision making.

Benzene research programme

For many years, the effects of benzene on human health have been of concern to health experts and air quality regulators. Because of these concerns, regulatory limits and technological developments have resulted in the reduction in benzene concentrations in transport fuels and in ambient air. The basis for today's worker and environmental benzene regulations in Europe and more globally was an epidemiological study completed in the 1980s. This study, called the 'pliofilm study', evaluated benzene-induced leukaemia in workers exposed to benzene vapour through the manufacturing of pliofilm polymers, mainly in the 1950s and 1960s. To fill some of the knowledge gaps from the pliofilm study, the petroleum industry sponsored three independent epidemiological studies of occupational exposure to benzene in the 1990s. While these studies did not find any relationship between benzene exposures and some types of leukaemia (e.g. chronic myeloid leukaemia and acute lymphatic leukaemia), higher incidences of other forms of leukaemia, including acute myeloid leukaemia and chronic lymphoid leukaemia, were observed in some of the studies.

To better understand the importance of these findings, a 'pooled analysis' of these epidemiology studies was initiated in 2006 to combine ('pool') and update the entire worker population. With support from API and other trade associations, CONCAWE coordinated this major research programme which integrated data from the three studies into a single dataset. This enabled the 'pooled' results to be analysed with a statistical confidence that could not be achieved from the individual studies.

The study did not find a clear relationship between various blood leukaemias and today's typical benzene exposure levels. This conclusion suggests that existing regulatory standards for benzene, such as occupational exposure limits, are already sufficient to protect worker health for benzene-related leukaemias. The study did identify a relationship between myelodysplastic syndrome and certain types of exposures but this new finding requires more investigation to determine whether it is of relevance for today's benzene exposure control strategies.

CONCAWE will continue to investigate and initiate, as needed, research programmes that provide insight on the benzene science.

Outlook

In addition to the regulatory requirements of REACH, in 2013 and beyond, various advisory and regulatory bodies will continue to formally assess the hazards/risks of petroleum substances and their constituents.

The three initiatives described above emphasise the need for a thorough scientific understanding and analysis of the cost-effective management of health risk. CONCAWE remains committed to this principle in its health science activities, as in all the other areas covered by its remit.

Petroleum products: looking back over the past 50 years

Petroleum product stewardship: to REACH and beyond

The field of petroleum products in CONCAWE has historically been concerned with product stewardship and chemicals control legislation relating to the production, marketing and use of petroleum substances. In 1977, the Petroleum Products Management Group issued its first report, titled *An assessment of precautionary labelling systems relating to the movement of petroleum products in bulk*, the objective of which was to promote the harmonisation of labelling for dangerous goods. Over the years CONCAWE has continued to provide guidance to its member companies on compliance with emerging and evolving EU legislation related to the control of chemicals.

Classification and labelling of chemicals—from DSD/DPD to CLP

The Dangerous Substances Directive (DSD), originally issued in 1967 and which entered into force in 1970, established criteria for the classification and labelling of chemicals based on their inherent physico-chemical and health properties. Since its original publication, the DSD was amended 31 times through Adaptations to Technical Progress (ATPs), which introduced requirements for the environmental classification and revisions/additions to human health effects. In 1980, CONCAWE published its first guidance on the classification and labelling of petroleum products marketed in the European Community, in advance of any formal evaluation by the European Commission on the classification of petroleum substances. Harmonized classifications for the carcinogenicity of petroleum substances were incorporated into the DSD beginning with the 19th and 21st ATPs in 1993. In 1995, CONCAWE updated its recommendations for classification and labelling of petroleum substances and introduced the concept of 'grouping'. The Dangerous Preparations Directive (DPD), first published in 1988 and recast in 1999, provided criteria for the classification and labelling of preparations. CONCAWE has kept abreast of subsequent legislative changes, updating its classification recommendations to enable industry to adopt a harmonized approach to the classification and labelling of petroleum substances.

Although petroleum substances are regulated by the same EU legislation as single-component chemicals, petroleum substances have a complex and varying composition, generally consisting of hundreds, if not thousands, of individual chemical components. For that reason, test methods developed for the classification of 'chemicals' cannot always be suitably applied to petroleum substances. Nevertheless, there was still a need for petroleum substances to be classified; in response to this need, CONCAWE had been instrumental in developing appropriate test methods for determining the aquatic toxicity and the inherent biodegradability of petroleum substances, and has published reports describing these.

At the United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992, agreement was reached on the development of an international programme for the classification of chemicals based on their physicochemical, health and environmental properties. This vision was realised with the publication of the first edition of the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) in 2003.

In 2007, the European Union issued a Regulation on the Classification, Labelling and Packaging (CLP) of Chemicals which incorporated major elements of the GHS. The CLP Regulation entered into force for substances in 2010 and will enter into force for mixtures (i.e. preparations) in 2015. At the time of writing this article, the CLP Regulation had been amended three times. CONCAWE continues to periodically update the report on classification and labelling recommendations, keeping it aligned with changes in the legislation and also with new information which becomes available on petroleum substances.

Restrictions/risk assessment—from MUDS/ESR to REACH

The Marketing and Use Limitations Directive (MUDS), first issued in 1976, introduced a framework for placing restrictions on the marketing and use of certain dangerous substances and preparations. Of particular note, the 14th ATP to the Directive, issued in 1994, banned substances classified as category 1 or category 2 carcinogens, mutagens and/or reproductive toxicants from sale to the general public. This ATP also included an exemption for the sale of motor fuels, mineral oil products intended for use as fuel in mobile or fixed combustion plants and for fuels sold in closed systems. These exemptions have been carried forward into the Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) which is discussed in more detail later in this article. Other restrictions impacting on petroleum substances that were introduced under MUDS include a restriction on the sale of lamp oils to the general public and restrictions on the level of certain polyaromatic hydrocarbons used in extender oils for the production of tyres. As before, these restrictions have also been carried forward into REACH.

The Existing Substances Regulation (ESR), published in 1993, required all producers and importers to supply certain information (i.e. classification, toxicity and ecotoxicity information, physico-chemical properties and production volumes) on high production volume chemicals to the European Commission. The ESR reflected the consolidation of petroleum substances into 'groups' based on their refining process. The objective was to compile the information into a database named IUCLID (International Uniform Chemical Information Database) which would be used as the source of information for subsequent risk assessments carried out by the Member States in accordance with the ESR.

In response to the obligations placed on industry, CONCAWE served to coordinate the compilation and submission of the required health and environmental information on petroleum substances into Harmonised Electronic Datasets (HEDSETS), as required by the ESR. This activity was particularly noteworthy in that it was carried out on behalf of the entire industry, including manufacturers and importers that were not members of CONCAWE.

Guidance for conducting risk assessments of single component chemicals has been developed under the Existing Substances Regulation. Though administered as a 'substance' under EU legislation, petroleum substances are, as mentioned earlier, different from single component chemicals. Assessing the risks to human health, and particularly to the environment, associated with such complex products was an entry into unchartered waters. In this context, CONCAWE introduced the concept of the Hydrocarbon Block Methodology which was accepted by the regulators and incorporated into the guidance for the ESR.

Recognizing the magnitude of the effort and time required to develop the detailed methodology for applying the Hydrocarbon Block Methodology to the environmental risk assessment of petroleum substances, CONCAWE embarked on a multi-year programme to develop PETRORISK to enable environmental risk assessments for petroleum substances using an EU decision-support instrument (EUSES). A second model, PETROTOX, was also developed to allow the prediction of aquatic toxicity of petroleum substances. Both models are publicly available and can be downloaded from the CONCAWE website (www.concawe.org).

Over the ensuing years, the slow progress under the ESR generated considerable debate amongst the European Commission, EU Member States, NGOs and industry with regard to the need to overhaul the existing legislative framework of chemicals control in the EU. In late spring 2003, the EU Commission issued a consultation document for REACH which proposed to shift the responsibility for undertaking the health and environmental risk assessment on substances from the authorities to industry. REACH was adopted by the EU Council and Parliament in 2006 and required the registration of chemicals manufactured or imported in quantities above 1,000 tonnes (and carcinogens above 1 tonne or substances classified as very toxic with long-term effects in the aquatic environment above 100 tonnes) to be submitted to a newly created European Chemicals Agency (in Helsinki) by 1 December 2010. For substances in lower tonnage bands, the regulation established two subsequent registration deadlines of 2013 and 2018.

The REACH regulation is extremely ambitious and complex. One of the basic principles of REACH is that there should be one registration per substance. Registrants were expected to organize themselves into Substance Information Exchange Fora (SIEF) to exchange the information required and to agree the common parts of the dossier that would be submitted by a Lead Registrant. As with the ESR, CONCAWE played a leading role in coordinating the industry response, and served as the Substance Information Exchange Facilitator of all SIEFs for petroleum substances that required registration.

The risk assessment process builds on the inherent toxicity/eco-toxicity of a substance (i.e. effects assessment) and introduces the aspect of exposure. The actual risk that a substance presents is characterized as its inherent toxicity coupled with the actual exposure, of either man or the environment, to the substance.

One of the core information needs for environmental risk assessments is a speciated compositional analysis which, in practice, is feasible only for light products. For high boiling substances (i.e. heavy fuel oils, base oils for lubricants, etc.), even state-of-the-art analytical techniques do not deliver a compositional analysis with the required level of detail. To overcome this limitation, CONCAWE proposed an alternative methodology, making use of physico-chemical properties rather than compositional information. The proposed methodology was presented to various European regulatory authorities and academics at a workshop in spring 2003. Response was favourable and CONCAWE has adopted this methodology for environmental risk assessment under REACH.

Table 1 Grouping scheme for petroleum substances

Stand-alone substances	MK1 Diesel Fuel Oxidized Asphalt Sulfur
Categories	Low Boiling Point Naphthas (Gasolines) Kerosines Straight-run Gas Oils Other Gas Oils Cracked Gas Oils Vacuum Gas Oils, Hydrocracked Gas Oils & Distillate Fuels Heavy Fuel Oils Components Other Lubricant Base Oils Highly Refined Base Oils Slack Waxes Foots Oils Petrolatums Paraffins and Hydrocarbon Waxes Untreated Distillate Aromatic Extracts Residual Aromatic Extracts Treated Distillate Aromatic Extracts Unrefined / Acid Treated Oils Bitumen

The European Inventory of Existing Commercial Chemical Substances (EINECS) includes nearly 700 petroleum substances. It would obviously not be feasible to conduct individual risk assessments on every one of them. CONCAWE is proposing a pragmatic methodology based on a refinement of the grouping scheme originally developed for classification purposes in the 1990s. The proposed grouping scheme for REACH consists of 18 'categories' and 3 'stand-alone substances', ranging from petroleum gases to bitumen, and grouping products and components of similar physico-chemical properties and uses (Table 1). Sulphur is also included as one of the 3 stand-alone substances because the oil industry is a major producer of sulphur as a consequence of product desulphurisation.

CONCAWE prepared registration dossiers for submission by the manufacturer/importer of the substance by the first deadline of 1 December 2010. The level of effort required to prepare these dossiers was significant; approximately 6,500 man-days of effort within a 3-year time-frame in the midst of new guidance being developed and/or revised in parallel. By February 2012, 4,194 registrations for 202 petroleum substances had been submitted to ECHA; 1,188 of these registrations were submitted by companies that are not members of CONCAWE. It must be mentioned that CONCAWE has provided all SIEF members with exhaustive guidance to support them throughout the REACH registration process; keeping this guidance updated in line with changes in, for example, the IT systems supporting REACH, remains a challenge which requires significant resources.

The categories have been developed to justify (e.g. for classification and labelling purposes) that tests carried out on samples of one category member can be considered applicable to all other category members, thus effectively reducing the number of expensive and time-consuming tests on petroleum substances. It must be noted that CONCAWE advocates applying the 'worst case' approach, by which all substances in a category receive the most stringent classification arising from the available tests on any substance in the category.

Not only does REACH cover the registration of substances but it also provides for the possibility of compliance checks to be carried out by ECHA to validate the completeness and adequacy of the information submitted by registrants. At the time of writing this article, ECHA has put in place a semi-automated system able to identify pitfalls in the registration dossiers. For example, substances registered only as intermediates need to comply with certain requirements which were not explicitly available at the time of submitting the dossiers; CONCAWE is also helping SIEF members to address these compliance issues.

When a data gap is found for a toxicity endpoint and the respective test involves vertebrate animals, registrants must submit a 'testing proposal' in the registration dossier, to be evaluated by ECHA; the tests can only be initiated when they are accepted by ECHA and the EU Member States. CONCAWE has submitted testing proposals for five categories and one stand-alone substance. At the time of writing this article, ECHA has already issued draft decisions on these testing proposals; these draft decisions actually reject virtually all of the testing proposals and contain a number of concerns and requests for additional information. CONCAWE is working on addressing these concerns within extremely tight deadlines, to prevent having to conduct the tests for all substances in a category instead of, as proposed by CONCAWE, testing just one substance representative of the worst case within the category.

Looking ahead

Although registration under REACH was a major achievement by CONCAWE and its member companies, in essence it only served the primary objective of allowing companies to stay in the market by obtaining REACH registration numbers. Along the upcoming years, ECHA will be digging more and more deeply into the information contained in the registration dossiers for petroleum substances, under the umbrella of the 'dossier evaluation' and 'substance evaluation' processes set out in the REACH text. At the time of writing this article, this process has already started and is requiring an ever-increasing effort from CONCAWE staff and experts from member companies.

The main areas to be addressed to support the registration of petroleum substances under REACH are:

- Substance identity—how to describe the chemical composition of petroleum substances taking into account their complexity and intrinsic variability and the vagueness of many CAS number definitions for petroleum substances.
- Grouping approach—how to support the categories set out for REACH to be able to limit the number of tests to be carried out for petroleum substances.
- Risk assessment—how to carry out this process taking into account the specific properties of petroleum substances, and how to justify carrying out risk assessments at the category level instead of for each substance individually.

It is also likely that some uses for some petroleum substances will fall under the REACH authorisation process (use as fuel is exempted from authorisation in REACH). If this is the case, significant effort and resources will be required to deal with the highly complex authorisation process.

In summary, REACH has only started and a significant amount of effort, possibly in the same order of magnitude of that carried out until now, will be needed from CONCAWE and its member companies.

Supporting the oil industry's commitment to safe operations

Understanding the causes of incidents is essential for improved safety management

The refining industry values the safety of its employees and staff working in its installations, as well as those living in communities near to its installations. Personal safety and safe operations are prerequisites for an industry that routinely produces and manages flammable and potentially explosive products. For this reason, safety considerations have been a major focus for CONCAWE and our member companies for as long as our association has existed.

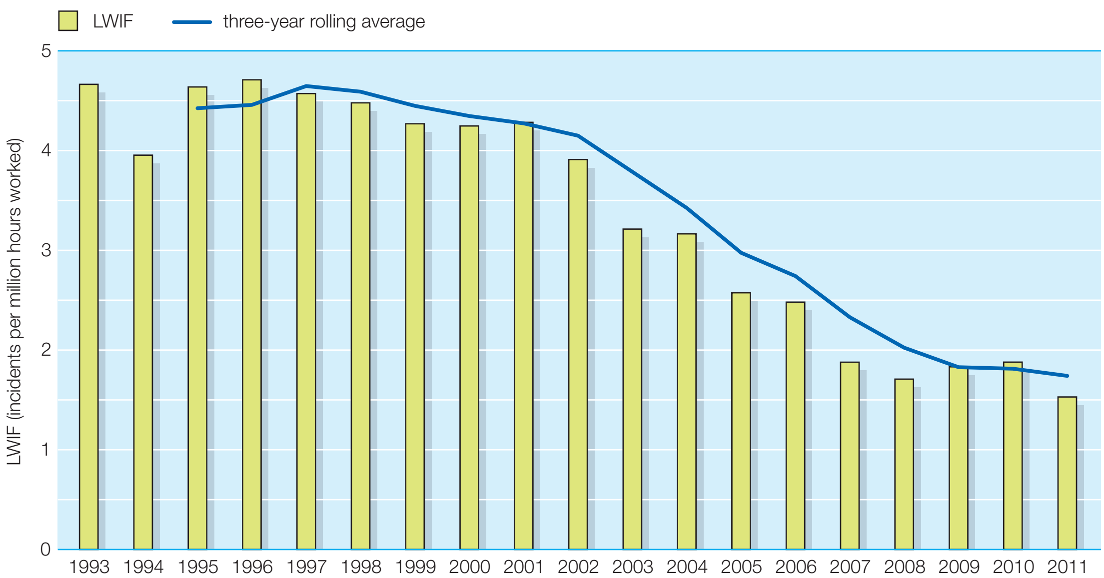
Since 1993, CONCAWE has compiled personal safety incident statistics for downstream oil industry workers on behalf of its member companies and published them in an annual report. These statistics demonstrate the oil industry's commitment to personal safety, and a marked improvement since the early 1990s (Figure 1). Thanks to its efforts, the oil industry can report much lower incident rates than industry at large with a lost time incident frequency of 1.5 compared with 22.7 for the EU-27. Through regular meetings of safety experts within CONCAWE, member companies also have the opportunity to exchange valuable information on actual incidents, and to share the lessons to be learned more generally on a range of safety management issues.

The CONCAWE structure provides a convenient and efficient channel through which the oil industry can put forward its opinions and comments during the legislation development process. CONCAWE has been involved in all major European legislative issues related to safety, particularly the Control of Major Accident Hazards Directive, better known as the 'Seveso' Directive, that was last updated in 2012 (2012/18/EU) to align it with other relevant legislation on product safety classification. The 'Seveso' Directive and its subsequent updates provided a new regulatory framework with which the oil refineries, depots and terminals had to comply, particularly with respect to information, permitting and operating requirements.

In 2009, CONCAWE member companies reported 999 safety incidents resulting in at least one lost working day and 11 regretted fatalities. These figures can be compared to 2,306,777 safety incidents resulting in at least three lost working days and 3,911 regretted fatalities for the entire EU-27 plus Switzerland and Norway.

CONCAWE report 7/10; and EUROSTAT, 2012 (http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Main_Page), 20 December 2012

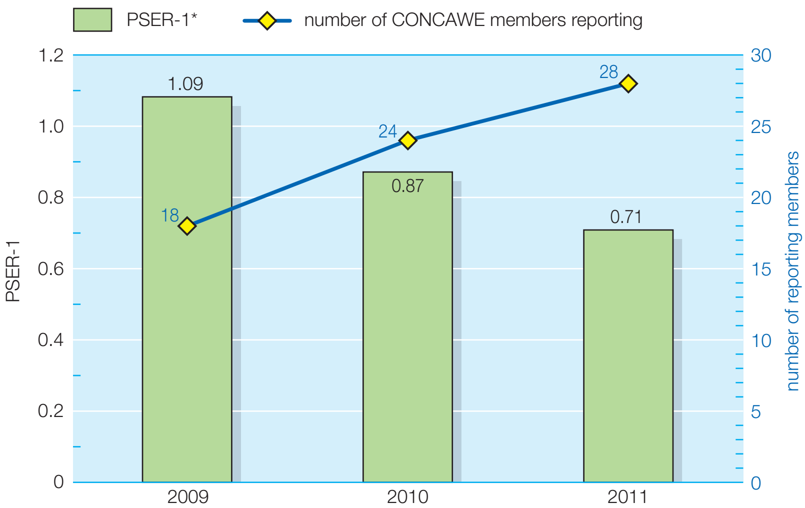
Figure 1 Lost work incident frequency (LWIF) per million hours worked, 1993–2011



In the past decade, industrial safety management has expanded to include process safety in response to challenges presented by, for example, the Seveso directives and several major incidents such as the Texas refinery explosion and the Buncefield terminal fire, both in 2005. CONCAWE therefore began gathering Process Safety Performance Indicator (PSPI) data, in 2009. The PSPI that was selected for survey is based on the American Petroleum Institute (API) guidance published in 2010[1]. This work involved many safety specialists from our member companies and will make it possible to compare the process safety performance of the European refining and distribution industry with that in other parts of the world. For 2011, 82% of CONCAWE's members reported their PSPI performance, demonstrating the importance of understanding and controlling the events that could initiate major incidents[2].

To date, CONCAWE is the only organisation that publishes these data, so comparing our results with those from other sectors is not yet possible. However, it is clear from the reactions of governmental officials and other third parties that our sector's openness on safety matters is a demonstration that our industry takes safety seriously and wants to learn from safety incidents. Our commitment to safety research and reporting will enable our industry to continually raise its safety standards and performance, and thereby protect the public, as well as employees, staff and business assets.

Figure 2 Process Safety Indicator Performance, 2009–2011



* PSER-1 the number of releases of hazardous substances per 1 million hours worked causing a fatality, injury, or fire or explosion leading to damages valued over € 25,000 or above set threshold values indicative to have the potential to cause these.

1 API (2010) ANSI/API Recommended Practice 754. *Process safety performance indicators for the refining and petrochemical industries*. Washington DC: American Petroleum Institute.

2 CONCAWE report 5/12

European cross-country oil pipelines

Monitoring the safety and environmental performance of Europe's oil pipelines

CONCAWE first became involved with oil pipeline safety issues in the mid-1960s when it started collecting information and statistics on incidents and spills related to European cross-country oil pipelines. Annual data have been collected since 1969 through a survey of pipeline operators. The first report was published the same year and annual reports have been published since 1972. Starting in 2006, the annual report has included all historical data with each report superseding the previous one.

Over a period of more than 40 years, the fraction of the total pipeline network covered by the CONCAWE survey has steadily increased, in particular through the incorporation of the NATO lines in 1988, the East German network in 1991 and a number of former Eastern bloc countries from the turn of the millennium. The statistics now cover most cross-country oil pipelines in the EU.

The so-called 'CONCAWE pipeline spillage report' has become a unique and trusted source of information throughout the industry and for other parties such as the EU institutions and Member States. Beyond the simple statistics, the large volume of data collected allows additional analyses to be made and conclusions to be drawn on what are the most important factors affecting the safety and integrity of cross-country oil pipelines in Europe.

Through this work CONCAWE has demonstrated that pipelines are a reliable and safe means of transporting oil products. Although pipeline spillage incidents do sometimes occur, they are usually infrequent and their consequences on the environment are limited.

Over the entire 40-year period, there have been 14 fatalities in 5 separate pipeline incidents and 3 injuries. With one exception, these fatalities were not caused by the leak per se but rather resulted from fires or explosions during clean-up and repairs subsequent to the leak, pointing towards deficient work procedures. Neither fatalities nor injuries involved members of the general public.

Over the years, the frequency of spillage incidents has consistently decreased (Figure 1).

The average volume of oil spilled has also decreased over time although the volume spilled from individual incidents can be variable. This decrease in average volume has been achieved through continuously improving maintenance practices and inspection techniques against a background of steadily increasing age of the pipeline system (most European pipelines were installed in the 1960s and 1970s). The data demonstrate that there is no causal link between the age of the pipeline and its failure rate.

Figure 1 EU cross-country oil pipelines spillage frequency

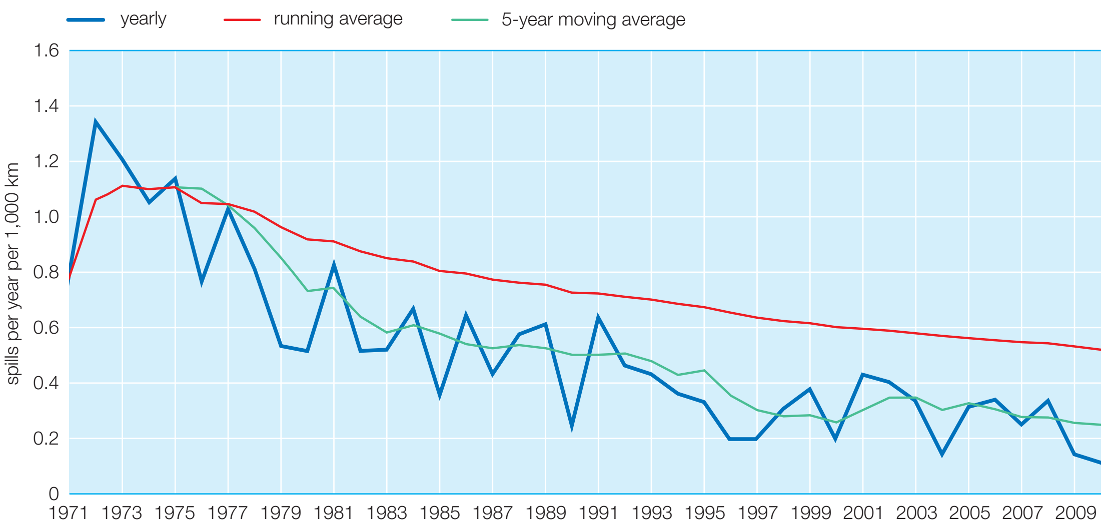
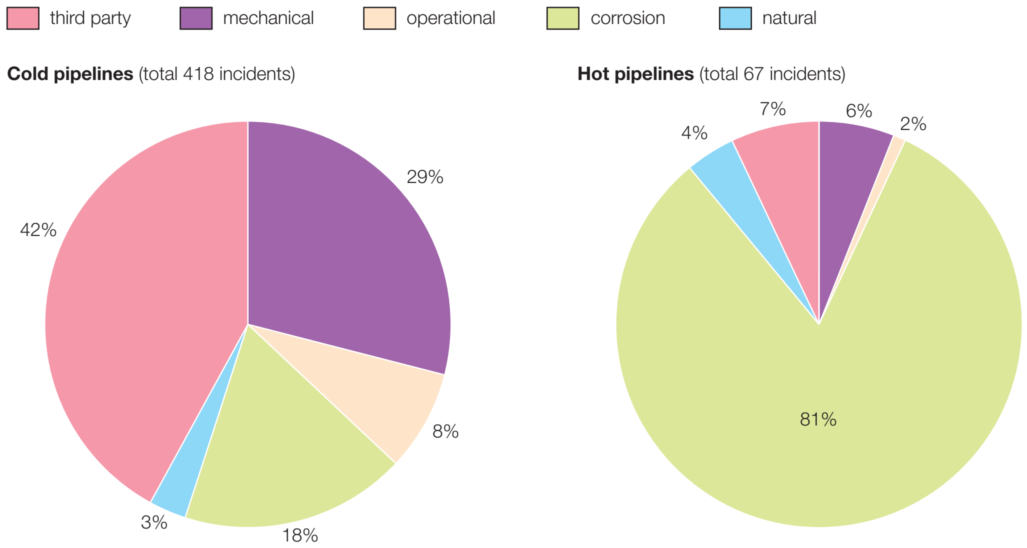


Figure 2 Distribution of major spillage sources for hot and cold pipelines, 1971–2011 (total 485 incidents)



A small proportion of the pipeline inventory consisting of insulated pipelines transporting hot products (mainly heavy fuel oil) has historically been mostly affected by external corrosion. For cold product pipelines, the largest fraction of pipeline spillage incidents is due to third parties, mostly during excavations unrelated to the existing pipelines.

Figure 2 illustrates the analysis of the causes of spillage incidents for both hot and cold product pipelines.

'Hot' pipelines represent less than 1% of the total inventory today but have accounted historically for 14% of the total reported spillage incidents. These pipelines are a small and decreasing part of the inventory and consist of insulated pipelines that transport heated products, mainly heavy fuel oil. These pipelines are affected mostly by external corrosion, and the majority have been phased out over the years, partly for this reason.

Third-party activities cause by far the largest proportion of pipeline spillage from cold pipelines. In the vast majority of such cases, pipeline spillage is unintended and is the result of excavation or other earth moving activities in the vicinity of the pipeline. There have also been a few cases of theft or attempted theft. Pipeline operators are keenly aware of the problem and strongly support the development of national and EU-wide so-called 'one-call' systems where all planned excavations must be declared and authorised. This approach is relatively simple to implement and will protect pipelines and other underground infrastructure.

The design, construction and operation of pipelines are already tightly regulated in most EU Member States. The CONCAWE performance statistics strongly support the view that a 'Seveso-type' EU-wide legislation for pipelines is unnecessary and would impose additional costs and administrative burdens on the industry for very little (if any) return.

CONCAWE's pipeline activities are carried out through the Oil Pipeline Management Group (OPMG), membership of which is open not only to CONCAWE member companies but also to all companies operating oil pipelines in Europe. In addition to compiling the annual statistics, this group provides a valuable forum for exchanging information on a number of topics, including: causes of incidents and lessons learned; developments in safety management; and pipeline condition monitoring, especially the use of in-line inspection tools.

The 'CONCAWE Oil Pipeline Operators Experience Exchange' (COPEX) seminar takes place every four years (the next one is planned for 2014). These seminars are open to all pipeline operators in Europe and beyond but only by invitation for suppliers of equipment and services (usually for specific presentations). As a result COPEX provides a unique opportunity for a broader, practical and objective exchange of knowledge, experience and best practices. These seminars have enjoyed continued popularity, which bears witness to their relevance. Proceedings of the 2010 COPEX are available on the CONCAWE website.

The evolution of oil refining in Europe

CONCAWE's contribution to understanding the challenges ahead

Back in 1963 when CONCAWE was founded, the world looked very different from what it is today, and so did the global and European refining industry. Oil product markets were expanding fast and new refineries were being built at a steady rate. The oil crisis of the 1970s brought an abrupt end to this, heralding a long era of consolidation and stepwise adaptation. At the same time the nature of the global oil business shifted from fully integrated companies producing, transporting and refining their own oil to a much more diversified situation where oil production ('upstream') and refining/distribution ('downstream') gradually became two essentially separate businesses. From being purely a 'cost centre' in an integrated chain, refining has become a separate activity in its own right, operating as a 'profit centre' between two global markets—crude oil and products—which, although not entirely independent, have their own dynamics and influences. In addition demand gradually shifted towards lighter products while the quality requirements on all products were considerably tightened.

This article explores the new challenges that these changes have imposed on EU refiners, and describes CONCAWE's contributions to understanding their impact on refinery production and investments.

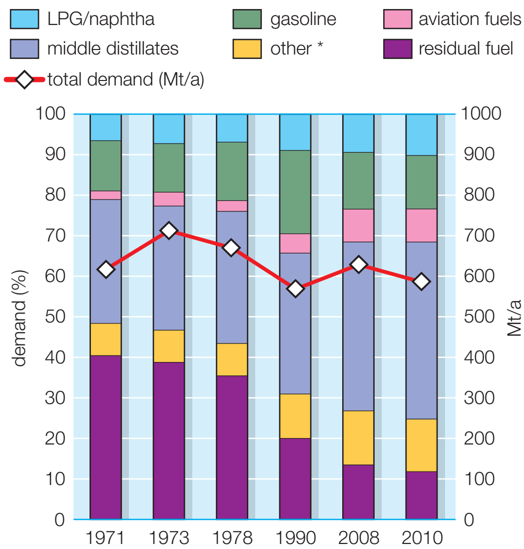
European petroleum product demand and crude supply

Figure 1 shows the evolution of petroleum product demand in what was to become the EU-15 over the past 40 years.

After a peak in 1973, total European demand for petroleum products has been on a slow decline. Crucially, the proportion of the various product groups has changed markedly. As demand for transport fuels soared, the market has demanded ever-increasing volumes of light products. At the same time the traditional markets for heavy fuel oil in power generation and heavy industries dwindled, a situation only partially offset by the buoyant marine bunker market. Today residual fuels account for just over 10% of the product barrel versus 40% in 1971, and so-called 'white' products (gas oils and lighter) now represent more than 70% (this is often referred to as the 'whitening of the barrel'). While this pattern has been repeated worldwide, Europe has also seen a specific trend: the widespread consumer uptake of the diesel passenger car from the early 1990s caused the demand for gasoline to decline while, also as a result of strong road freight growth, demand for diesel fuel soared. This is illustrated in

Below: after a peak in 1973, total demand for petroleum products in the EU-15 has been on a slow decline while the proportion of residual fuel decreased four-fold.

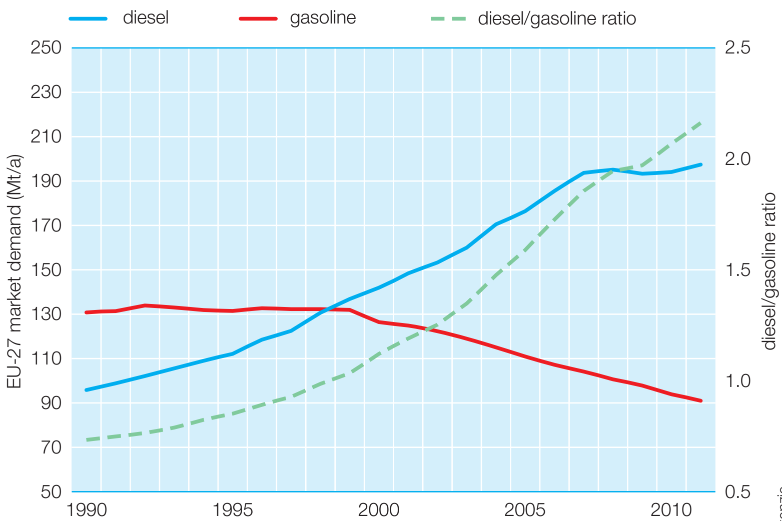
Figure 1 The evolution of petroleum product demand in what was to become the EU-15 over the past 40 years



* The 'other' category mostly consists of speciality products such as lube oils, bitumens, solvents, etc.

Source: International Energy Agency

Figure 2 The diesel to gasoline ratio in EU-27 countries, 1990–2011



Above: the high uptake of diesel passenger cars and strong road freight growth have caused the diesel to gasoline ratio in EU-27 countries to triple over the past two decades.

Source: Wood Mackenzie

Figure 2 which shows that the EU-27 diesel to gasoline ratio has virtually tripled in the past two decades.

During the same period, major changes were introduced to fuel specifications, both to satisfy engine performance requirements and to comply with increasingly stringent emission regulations. Until the late 1980s, fuel quality specifications were primarily an industry matter guided by engine requirements and storage transport and handling imperatives. Only a few key properties such as gasoline octane were regulated and, in Europe, this was done independently by each national government. From the early 1990s, as a result of progress in the implementation of the EU single market and the development of EU-wide environmental laws, fuel specifications were gradually harmonised across the EU and came under the jurisdiction of the EU Commission. Responding to concerns about the impact of road transport on air quality, the EU Commission set out on an ambitious programme to drastically reduce vehicle emissions, triggering the introduction of new technologies such as the three-way catalyst for gasoline vehicle exhaust and later the particulate filter for diesel vehicles. In turn, these technologies placed new constraints on fuel quality, while other associated legislation directly required adaptations of specific quality parameters. The so-called Fuel Quality Directive was first promulgated in 1993[2] and has been updated several times since then. Table 1 summarises the evolution of the most crucial quality parameters in Europe for the main transport fuels, as stipulated by European standards EN228 (gasoline) and EN590 (diesel fuel). The phase out of lead in the early 1990s was the first major quality challenge faced by refiners, requiring a complete rethink of the way gasoline was made. The problem was later further complicated by additional restrictions on a number of traditional gasoline components (aromatics, olefins, etc.). Arguably though, the biggest issue for refiners was the almost total removal of sulphur in road fuels, with sulphur content reduced by two orders of magnitude.

[2] Directive 93/12/EEC relating to the sulphur content of certain liquid fuels, dated 23 March 1993

Table 1 The quality requirements of EU road fuels have been fundamentally changed in the past two decades

		Year	1994	1995	1996	2000	2005	2009
Unleaded gasoline (standard grade)						**EN228**		
Sulphur	ppm m/m	max	1000	500		150	50/10	10
Benzene	% v/v	max	5			1		
Aromatics	% v/v	max	Not specified			42	35	
Olefins	% v/v	max	Not specified			18		
Oxygen	% m/m	max	2.5[a]			2.7		
Vapour pressure (summer)	kPa	max	up to 80			60[b]		
Diesel (standard grade)						**EN590**		
Cetane Index		min	46					
Cetane Number		min	49			51		
Sulphur	ppm m/m	max	2000		500	350	50/50	10
Density	kg/m	min	820					
		max	860			845		
T95	degrees C	max	370			360		
Polyaromatic hydrocarbons	% m/m	max	Not specified			11		
Lubricity	μm @ 60˚C	max	Not specified		460			

[a] Up to 3.7% at Member State discretion. Individual limits apply to specific compounds.

[b] 70 kPa maximum allowed in Member States with arctic or severe winter conditions.

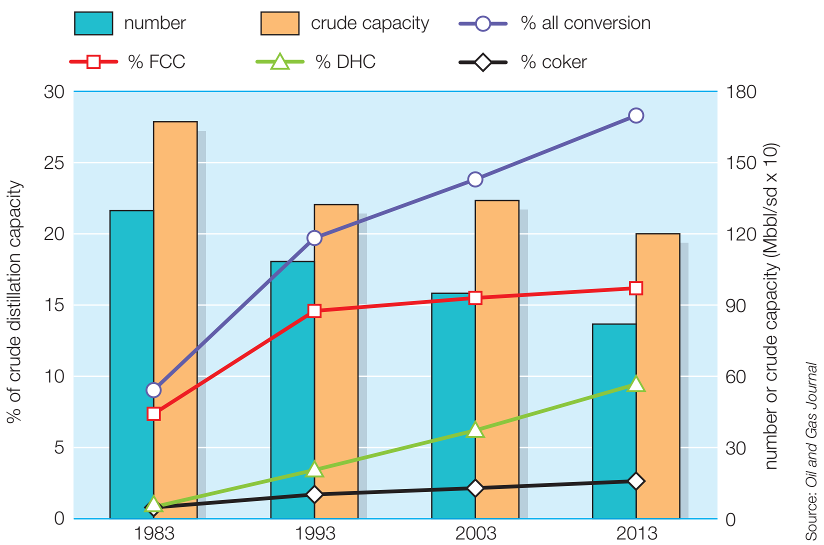
During the period, there were also major changes to the crude oil production and supply routes. Until the late 1960s there were relatively few producing countries and production was mostly handled by large international integrated oil companies operating concessions in the host countries. The oil companies would also transport and refine crude oil mostly in their own refineries.

From the early 1970s oil producing countries increasingly took direct charge through national oil companies. At the same time rising demand led to growth in the number of oil producing regions. This resulted in the gradual separation of crude production from refining and distribution and the creation of an open crude market. From virtually complete reliance on the Middle East, European supply was gradually diversified to include the North Sea, North and West Africa and the Commonwealth of Independent States. The availability of relatively light, low sulphur crudes from these regions helped in meeting the growing demand for lighter products.

Below: the number of EU-15 refineries has decreased over the years while the remaining sites became increasingly complex.

Although the recent worldwide trend is towards a marginally heavier crude mix, Europe still has and is expected to retain good logistic access to major light crudes, the declining North Sea supply being replaced by new resources from West Africa and the Caspian area.

Figure 3 Population, capacity and complexity trends of EU-15 refineries, 1983-2013



Refining challenges

In order to continue to supply the market, the refining industry, both globally and in Europe, has had to respond and adapt to the momentous changes in the composition of the demand barrel and the more stringent product specifications, while also reducing direct emissions to air and water from the refining sites. This has required large capital expenditures in refineries.

Over the years many, mostly smaller sites gradually closed down while larger ones, where investments could be justified, were being modernised, upgraded and expanded. To respond to the 'whitening of the barrel' refiners have had to build 'conversion' facilities to convert residual material to distillates. Figure 3 shows the evolution in the past 30 years of the number of refineries in the EU-15, their crude oil processing capacity and the ratios of different types of conversion capacity to crude capacity. From 130 in 1983, there are now 82 active refineries in the EU-15 (including specialist bitumen and lube-oil refineries). In line with the total demand, crude capacity decreased at first but has been stable since the early 1990s, although recent refinery closures have resulted in a capacity reduction of 11% over the decade from 2003–2013. However, the conversion intensity showed a very large increase at first with the addition of mostly catalytic cracking capacity and, more recently of hydrocracking capacity (a technology that allows production of more middle distillates and less gasoline). Coking also makes a growing contribution although it is not as widespread in Europe as in, for example, North America where the market for heavy fuel oil is small.

Lead removal, sulphur reduction and other quality changes required investment in additional facilities, further increasing the complexity of refineries.

CONCAWE's contribution

CONCAWE's role and contribution to these matters is relatively recent. The fuels and emissions activity started in the mid 1980s to investigate issues at the interface between fuels and vehicles. When comprehensive, game-changing EU fuel legislation came to pass in the early 1990s, it became clear that, in addition to investments in additional conversion capacity required to meet light product demand, the EU refining industry would face significant additional investments to meet the new specifications notably with regard to sulphur content.

Against this background the Refinery Planning Advisory Group (RPAG), later renamed as Refinery Technology Support Group (RTSG), was instituted with the task of developing and maintaining tools to evaluate the potential cost of fuel quality legislation on the refining industry. A single refinery can be complex and there are often many ways in which it can respond to a given challenge. This is even truer at the level of a country or indeed of the whole EU. The RPAG therefore set out to develop an EU-wide refining model, based on the linear programming (LP) methodology, which would identify the least-cost investment options for EU refineries to meet anticipated market demand in terms of both quality and quantity.

LP models are commonly used to programme and optimise refineries in the short term, and are normally driven by a combination of supply and demand constraints and prices. For the CONCAWE model the objective was more to understand how the total EU refining 'system' needed to evolve in order to meet demand. For that reason the model was run in an over-constrained manner with fixed demands and a virtually fixed crude supply representative of the European slate, the main degree of freedom being investment in new facilities. This made the outcome insensitive to prices which, for such medium-term studies, are extremely speculative.

The model became operational in 1993 and supported many studies and reports, particularly on the impact of the specifications that resulted from the Auto/Oil programmes, such as the April 1999 report (no. 99/56), *EU oil refining industry costs of changing gasoline and diesel fuel characteristics*.

By the early 2000s, although investment costs remained a crucial consideration, the focus shifted towards energy efficiency and carbon emissions, the latter having become a major element of the overall impact of a particular legislative initiative. The EU-refining model could be put to task to quantify the changes in refinery CO_2 emissions to be expected as a result of general product demand and specific fuel quality changes, but it first needed a major revamp to ensure that it was 'carbon-balanced', i.e. that the conservation of carbon was respected in all sub-sections of the model. This proved to be a delicate but eventually successful task and resulted in, to our knowledge, the first such carbon-balanced model.

In the course of the past decade, the RTSG has conducted a series of studies to estimate the potential impact of various legislative packages on EU refineries' investment costs, energy consumption and CO_2 emissions, in the expected supply and demand environment. The most recent of these studies was published in 2009 as CONCAWE Report 3/09, *Impact of marine fuels quality legislation on EU refineries at the 2020 horizon*.

In the context of the 'Well-to-Wheels' analysis of vehicle fuels and powertrains in Europe[3], the EU refining model was also used to estimate the marginal energy and CO_2 emissions associated with the production of gasoline and diesel in Europe.

Since 2009 the activities of the RTSG fall under the Refinery Management Group (RMG), which includes task forces that have recently been called upon to investigate other technology-related refinery issues such as the potential for application of CO_2 capture and storage in EU oil refineries (Report 7/11), EU refinery energy systems and efficiency (Report 3/12) and developing a methodology for an EU refining industry CO_2 emissions benchmark (Report 9/12).

Many technological and economic challenges lie ahead for the EU refining industry, mainly driven by the growing imbalance between diesel and gasoline demand and the reduction of marine fuel sulphur content in 2015 and 2020. CONCAWE's RMG will continue to use its unique EU refinery modelling capabilities to provide insightful analysis and reporting on the impact of such legislative and demand-related changes on the EU refining industry.

[3] The 'Well-to-Wheels analysis of automotive fuels and powertrains in the European context' is a joint initiative of the EU Commission's Joint Research Centre (JRC), the European Council for Automotive Research (EUCAR) and CONCAWE.

Abbreviations and terms

ANSI	American National Standards Institute
API	American Petroleum Institute
ATP	Adaptation to Technical Progress
BAT	Best Available Techniques
BAT REF or BREF	BAT Reference document. Full title: 'Reference Document on Best Available Techniques for ….' (A series of documents produced by the European Integration Pollution Prevention and Control Bureau (EIPPCB) to assist in the selection of BATs for each activity area listed in Annex 1 of Directive 96/61/EC)
CAFE	Clean Air For Europe
CEN	European Committee for Standardization
CIAM	Centre for Integrated Assessment Modelling
CIS	Common Implementation Strategy
CLRTAP	Convention on Long-range Transboundary Air Pollution
CLP	Classification, Labelling and Packaging (of Chemicals)
COPEX	CONCAWE Oil Pipeline Operators Experience Exchange
DHC	Distillate Hydrocracker
DPF	Diesel Particulate Filter
DNEL	Derived No-Effect Level
DPD	Dangerous Preparations Directive
DSD	Dangerous Substances Directive
EC	European Commission
ECA	Emissions Control Area
ECHA	European CHemicals Agency
ECO	Environmental Citizens' Organisation
EINECS	European Inventory of Existing Commercial Chemical Substances
EMEP	European Monitoring and Evaluation Programme
EPA	Environmental Protection Agency (US)
EPEFE	European Programme on Emissions, Fuels and Engine technologies
E-PRTR	European Pollutant Release and Transfer Register
EQS	Environmental Quality Standard
ESCAPE	European Study of Cohorts for Air Pollution Effects
ESR	Existing Substances Regulation
ETBE	Ethyl Tertiary-Butyl Ether
EUCAR	European Council for Automotive Research and development
EUSES	European Union System for the Evaluation of Substances
FAME	Fatty Acid Methyl Ester
FCC	Fluid Catalytic Cracker
FEMG	Fuels and Emissions Management Group
FQD	Fuel Quality Directive (2009/30/EC)
GHG	Greenhouse Gas
GHS	Globally Harmonised System of classification and labelling (United Nations)
HEDSETS	Harmonized Electronic Datasets
HRAPIE	Health Risk of Air Pollution In Europe
IED	Industrial Emissions Directive
IIASA	International Institute for Applied Systems Analysis
IMO	International Maritime Organization
IARC	International Agency for Research on Cancer
IP	Institute of Petroleum (UK)
IPPC	Integrated Pollution Prevention and Control (EU Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control)
IUCLID	International Uniform Chemical Information Database
JRC	Joint Research Centre of the European Commission
LP	Linear Programming
LPG	Liquefied Petroleum Gas
LWIF	Lost Workday Injury Frequency
MARPOL	1973 International Convention for the Prevention of Pollution from Ships
MTBE	Methyl Tertiary-Butyl Ether
MSFD	Marine Strategy Framework Directive
MUDS	Marketing and Use limitations Directive
NEC(D)	National Emission Ceilings (Directive)
NEDC	New European Driving Cycle
NGO	Non-Governmental Organisation
NO_x	Nitrogen Oxides
OPMG	Oil Pipeline Management Group
PM	Particulate Matter or Mass
PN	Particle Number
PPM	Parts Per Million
$PM_{2.5}/PM_{10}$	Particulate matter with an aerodynamic diameter less than or equal to 2.5/10 µm
PSER	Process Safety Event Rate
PSPI	Process Safety Performance Indicator
RAE	Residual Aromatic Extract
RAINS	Regional Air Pollution Information and Simulation model (A tool developed by IIASA for analysing alternative strategies to reduce acidification, eutrophication and ground-level ozone in Europe)
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RED	Renewable Energy Directive (2009/28/EC)
REVIHAAP	Review of the Evidence on Health Aspects of Air Pollution
RMG	Refinery Management Group
RPAG	Refinery Planning Advisory Group
RTSG	Refinery Technology Support Group
RUFIT	Rational Use of Fuels in private Transport
SCALE	Science-based, Children-focussed, Awareness-raising, using Legal instruments, and constantly Evaluated
SECA	SO_x Emissions Control Area
SIEF	Substance Information Exchange Forum
SO_2	Sulphur Dioxide
STEERS	Strategic Toolkit for Evaluating Emission Reduction Scenarios
TFEIP	Task Force on Emission Inventories and Projections
TSAP	Thematic Strategy on Air Pollution
TWG	Technical Working Group
UNECE	United Nations Economic Commission for Europe
UWWT	Urban Waste Water Treatment (Directive)
VE3SPA	Validation of ESCAPE Exposure EstimateS using Personal exposure Assessment
VOC	Volatile Organic Compounds
WEA	Whole Effluent Assessment
WFD	Water Framework Directive
WSMG	Water and Soil Management Group
WHO	World Health Organization
WTW	Well-to-Wheels

CONCAWE contacts

Director General

Chris Beddoes
Tel: +32-2 566 91 16 Mobile: +32-473 11 09 45
E-mail: chris.beddoes@concawe.org

Former Secretary General

Michael Lane
Tel: +32-2 566 91 61 Mobile: +32-496 27 37 23
E-mail: michael.lane@concawe.org

Office management and support

Finance, Administration & HR Manager
Didier De Vidts
Tel: +32-2 566 91 18 Mobile: +32-474 06 84 66
E-mail: didier.devidts@concawe.org

REACH Implementation Officer
Sophie Bornstein
Tel: +32-2 566 91 68 Mobile: +32-497 26 08 05
E-mail: sophie.bornstein@concawe.org

Marleen Eggerickx
Tel: +32-2 566 91 76
E-mail: marleen.eggerickx@concawe.org

Sandrine Faucq
Tel: +32-2 566 91 75
E-mail: sandrine.faucq@concawe.org

Anja Mannaerts
Tel: +32-2 566 91 73
E-mail: anja.mannaerts@concawe.org

Barbara Salter
Tel: +32-2 566 91 74
E-mail: barbara.salter@concawe.org

Julie Tornero
Tel: +32-2 566 91 73
E-mail: julie.tornero@concawe.org

Technical Coordinators and Associates

Air quality
Pete Roberts
Tel: +32-2 566 91 71 Mobile: +32-494 52 04 49
E-mail: pete.roberts@concawe.org

Air quality—Research Associate
Lucia Gonzalez Bajos
Tel: +32-2 566 91 64 Mobile: +32-490 11 04 71
E-mail: lucia.gonzalez@concawe.org

Fuels quality and emissions
Ken Rose
Tel: +32-2 566 91 69 Mobile: +32-499 97 53 25
E-mail: ken.rose@concawe.org

Health
Arlean Rohde
Tel: +32-2 566 91 63 Mobile: +32-495 26 14 35
E-mail: arlean.rohde@concawe.org

Petroleum products • Risk assessment
Francisco del Castillo Roman
Tel: +32-2 566 91 66 Mobile: +32-490 56 84 83
E-mail: francisco.delcastillo@concawe.org

Refinery technology
Alan Reid
Tel: +32-2 566 91 67 Mobile: +32-492 72 91 76
E-mail: alan.reid@concawe.org

Water, soil and waste • Safety • Oil pipelines
Klaas den Haan
Tel: +32-2 566 91 83 Mobile: +32-498 19 97 48
E-mail: klaas.denhaan@concawe.org

CONCAWE
Boulevard du Souverain 165, B–1160 Brussels, Belgium
Telephone: +32-2 566 91 60 • Telefax: +32-2 566 91 81
info@concawe.org • www.concawe.org

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